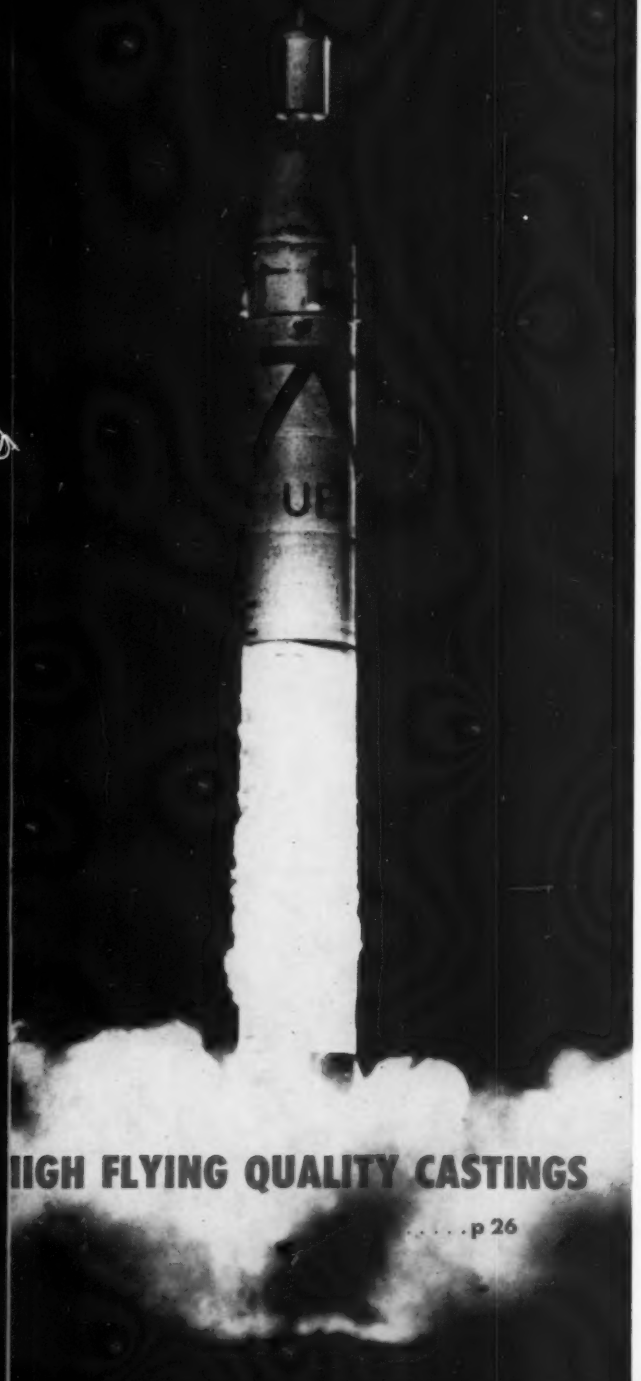
modern castings

AFS AUGUST, 1959



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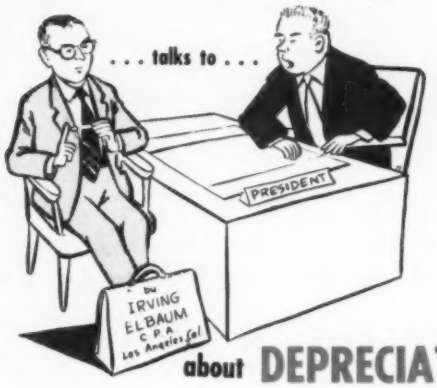
tax consultant foundry operator



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DON'T ALLOY YOUR IRON WITH WATER

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GREEN SAND MOLDING STRIKES BACK

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900,000 TONS OF STRONGER CAST IRON PIPE

Almost a million net tons of cast iron are produced annually to provide a vast network of pipes for potable, process, fire protection and sewer systems. A failure anywhere in this country-wide network, could result in losses of thousands of dollars.

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august, 1959
vol. 36, no. 2

modern castings

the technical magazine of the metalcasting industry

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future meetings and exhibits

AUGUST

6-7 . . AFS Board of Directors, *Annual Meeting*. Ambassador West Hotel, Chicago.

SEPTEMBER

13-18 . . American Chemical Society, *Fall Meeting*. Atlantic City, N. J.

15-17 . . American Die Casting Institute, *Annual Meeting*. Edgewater Beach Hotel, Chicago.

21-22 . . Steel Founders' Society of America, *Fall Meeting*. The Homestead, Hot Springs, Va.

24-26 . . *AFS Missouri Valley Regional Foundry Conference*. University of Missouri, School of Mines & Metallurgy, Rolla, Mo.

28-Oct. 1 . . Association of Iron and Steel Engineers, *Annual Convention*. Sherman Hotel, Chicago.

28-Oct. 1 . . American Welding Society, *Fall Meeting*. Hotel Sheraton-Cadillac, Detroit.

29-Oct. 1 . . National Association of Corrosion Engineers, *Western Regional Conference*. Bakersfield Inn, Bakersfield, Calif.

OCTOBER

1-2 . . AFS *Empire State Regional Foundry Conference*. Drumlins Country Club, Syracuse, N. Y.

2-3 . . AFS *Northwest Regional Foundry Conference*. Benjamin Franklin Hotel, Seattle.

3-10 . . International Committee of Foundry Technical Associations, *International Foundry Congress*. Madrid, Spain.

7-9 . . Gray Iron Founders' Society, *Annual Meeting*. Fairmont Hotel, San Francisco.

8-9 . . AFS *Michigan Regional Foundry Conference*. Pantlind Hotel, Grand Rapids, Mich.

8-10 . . American Society of Tool Engineers, *Semi-annual Meeting*. St. Louis.

10-13 . . Conveyor Equipment Manufacturers Association, *Annual Meeting*. Grand Hotel, Point Clear, Ala.

11-16 . . American Society for Testing Materials, *Pacific Area National Meeting & Exhibit*. Sheraton Palace Hotel, San Francisco.

12-17 . . National Industrial Sand Association, *Semi-annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

15-17 . . Foundry Equipment Manufacturers Assn., *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

16-17 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

19-23 . . National Management Association, *Annual Meeting and National Conference*. Statler-Hilton Hotel, Detroit.

21 . . Cast Bronze Bearing Institute *Annual Meeting*. Bedford Springs Hotel, Bedford, Pa.

22-23 . . AFS *Ohio Regional Foundry Conference*. Deshler-Hilton Hotel, Columbus, Ohio.

22-24 . . Non-Ferrous Founders' Society, *Annual Meeting*. Bedford Springs Hotel, Bedford, Pa.

29-30 . . AFS *Purdue Metals Casting Conference*. Purdue University, West Lafayette, Ind.

NOVEMBER

2-6 . . American Society for Metals, *National Metal Exposition & Congress*. International Amphitheatre, Chicago.

6-7 . . National Foundry Association, *Annual Meeting*. Roosevelt Hotel, New York.

20-21 . . AFS *East Coast Regional Foundry Conference*. Statler-Hilton Hotel, New York.

DECEMBER

2-4 . . Metallurgical Society of American Institute of Mining, Metallurgical & Petroleum Engineers, *Electric Furnace Conference*. Cleveland Hotel, Cleveland.

1960

MAY

9-13 . . AFS *64th Annual Castings Congress & Foundry Show*. Convention Hall, Philadelphia.

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Success story reported by Ken Armstrong, Molding Foreman, Koehring Company, Foundry Division, Milwaukee

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Circle No. 147, Page 139-140

the editor's report

by Jack Schaum

■ **Steel castings with 290,000 psi ultimate tensile strength** . . . 233,000 psi yield strength . . . and 5.5 per cent ductility are now being made by American Brake Shoe Co., Mahwah, N.J. Just about a year ago the foundrymen were challenged by J. K. Dietz, Chance Vought Aircraft, Inc., in a talk before the Investment Casting Institute, to supply castings with 260,000 psi tensile strength and enjoy a 125 million dollar casting market. Brake Shoe is to be commended for picking up the gauntlet and "saving-face" for the metalcasting industry. These super-castings are made of hi-purity type 8740 steel . . . weight 250 lb . . . have 36-in. diameter, 0.125-in. section . . . and are cast in ceramic molds. We would like to hear from any other foundries that are pushing tensile barriers toward new horizons.

■ **Green Sand Molding Fights Back** . . . read in this issue how green sand molding has proven itself competitive by taking the Pontiac crankshaft job away from shell molding and forging at Central Foundry Div., GMC.

■ **Only 75 lb of CO_2 gas** are needed to cure 18,000 lb of sand molds on a New Jersey foundry production line. This is only 0.42 per cent of the sand weight. Gassing time varies from 10 to 12 seconds. And by using a 3.25 to 1 ratio sodium silicate base, cost of binder is cut to 1.2 cents per pound. Success of this operation stems largely from vacuum degassing of mold before introducing CO_2 gas.

■ **Super adhesives** have opened the door to cast-glued assemblies to compete with the cast-welded combos. One of next year's automotive intake manifolds will be assembled by cementing together three individual aluminum die castings—thanks to a new super adhesive.

■ **A $2.5 million plant conversion to shell molding** of steel castings is underway at the E. Chicago plant of American Steel Foundries. New facilities should be ready for action by the end of this year. Already installed is the largest shell molding machine in the world with a plate size of 54 x 94 inches.

■ **Lost Pattern Process** . . . John Dewey, Dow Chemical Co., has developed a foamed plastic pattern material which can be rammed-up in sand and left in the mold. Pattern quickly evaporates and burns out of the mold cavity when molten metal contacts it. Has interesting possibilities in prototype or experimental work where only one casting is needed.

■ **Have you tried this new product** . . . copper-nickel welding electrode containing tungsten carbide particles. With an oxyacetylene torch you can lay this tough wear-resistant mix on any metal except aluminum. One foundry applied it to a steel bolt head and used the bolt to drill concrete and grind out burned-in sand cores. In one instance, 20 min core grinding replaced 16 hr. of chipping.

■ **Magnesium can be cast in plaster molds** . . . but just be sure you have at least 3% potassium fluoroborate and sulfur in the mix to inhibit the violent Mg - H_2O reaction!

■ **Ever wonder** how many castings a day are ground by one of those fast workers on the snagging wheel in a malleable cleaning department? In a talk at the Malleable Founders Society T&O Conference, E. F. Price, Dayton Malleable Iron Co., told how they developed a special fixture which permitted one man to grind 13,800 castings during an 8-hr shift.

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products and processes

CO_2 GASSER . . . pressure gassing machine features 25 x 30-in. conveyorized

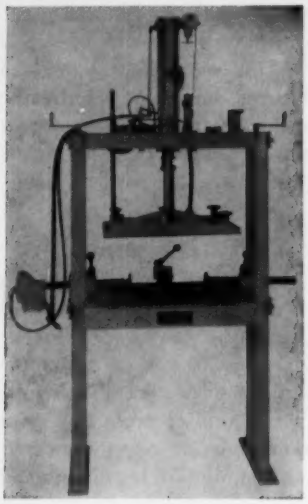


table and cast spacers for quick vertical height adjustment, 20 x 24-in. gassing head and timing controls *Alphaco, Inc.*
For More Information, Circle No. 1, Page 139-140

MELTING FURNACE . . . new reverberatory furnace claims innovations in design which reduce time and cost of melting gray iron, copper, bronze, brass, aluminum. Adaptability to melting of ductile iron is principal feature. *U. S. Smelting Furnace Co.*
For More Information, Circle No. 2, Page 139-140

HIGH TEMP REFRACTORY . . . plastic refractory for extremely high temperature service in electric furnace roofs is recent development. *Plibrico Co.*
For More Information, Circle No. 3, Page 139-140

BIN VIBRATORS . . . two vibrators for moving stubborn materials in larger, heavier bins are being marketed. One model is "semi-noiseless." *Eriez Mfg. Co.*
For More Information, Circle No. 4, Page 139-140

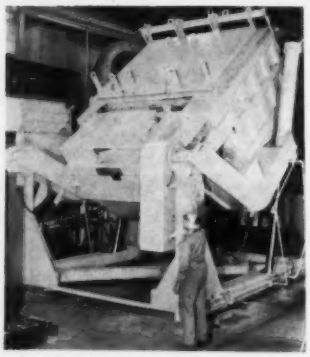
TENSILE TESTER . . . vertical, bench-mounted, can also perform compression tests—10,000-lb capacity. *Steel City Testing Machines, Inc.*
For More Information, Circle No. 5, Page 139-140

HOLDING FURNACES . . for aluminum die casting and permanent mold operations are available in new line of units of 500 to 2000-lb capacity. Builder claims all units are exceptionally small and compact. *Stroman Furnace & Eng. Co.*
For More Information, Circle No. 6, Page 139-140

GLASS FOR METALCASTING . . fused silica glass is new product recommended for: permanent molds, permanent back ups for shell molds, one-piece furnace hearths and crucibles for induction melting. *Glasrock Corp.*
For More Information, Circle No. 7, Page 139-140

GRINDING WHEEL EFFICIENCY . . is said to be improved 300 per cent when abrasive grains are treated with A-1100 Silane coating. *Silicones Div., Union Carbide Corp.*
For More Information, Circle No. 8, Page 139-140

HOLDING FURNACE . . . 30,000-lb unit with three-section hydraulically operated cover is available. Aluminum in-



duction holding furnace is said to be designed for continuous service. *Lindberg Engineering Co.*
For More Information, Circle No. 9, Page 139-140

NONDESTRUCTIVE TESTER . . . tests hardness, heat treat condition; sorts mixed nonmagnetic metals; checks tensile strength of aluminum. Operates by measuring electrical conductivity. Portable unit, 4-1/2 lb. *Magnaflux Corp.*
For More Information, Circle No. 10, Page 139-140

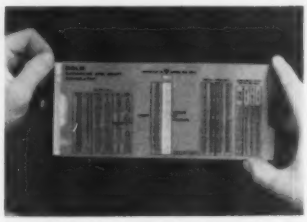
HIGH SPEED DIE CASTER . . . 125 ton, 1000 cycle per hour unit is first high speed, small capacity unit with unit steel frame construction designed to withstand high cycling speeds. *Lester-Pheonix, Inc.*
For More Information, Circle No. 11, Page 139-140

ALUMINUM ALLOY . . . with unusually high physicals is designed for sand and permanent mold castings for missiles and aircraft. Alloy MA-356 produces castings to exceed MIL-C-21180A. *Rolle Mfg. Co.*
For More Information, Circle No. 12, Page 139-140

ABRASIVE-RESISTANT METAL . . . is available in cleaning stars, grinding balls, friction bearings and parts for abrasive-material handling equipment. *Quincy Foundry Inc.*
For More Information, Circle No. 13, Page 139-140

DIE CORES . . . for die casting can now be made from a new molybdenum base alloy which has superior resistance to heat checking. *Die Casting Research Foundation.*
For More Information, Circle No. 14, Page 139-140

SHRINKAGE AND DRAFT CALCULATOR . . . plastic slide-chart provides



time-saving method of determining draft and shrinkage. *Kelm Mfg. Co.*
For More Information, Circle No. 15, Page 139-140

SPECTROMETER . . . line of direct reading spectrometers has been re-engineered and improved to allow greater number of elements to be analyzed at one time. *Baird-Atomic, Inc.*
For More Information, Circle No. 16, Page 139-140

CORE VENT . . . of nylon is self cleaning; has clear passage area; cannot be damaged by crushing or hammering. *Martin Engineering Co.*
For More Information, Circle No. 17, Page 139-140

CO_2 SHELL COAT . . . resin spray or dip for CO_2 cores provides strength, finish and improved collapsibility. *Para Products Div.*
For More Information, Circle No. 18, Page 139-140

LOW-CARBON FERROCHROME . . . Simplex ferrochrome is said to be fastest dissolving low-carbon ferrochrome for stainless steel. Alloy has lowest carbon commercially available in a ferrochrome. *Union Carbide Metals Co.*
For More Information, Circle No. 19, Page 139-140

BARREL FINISHING . . at low cost is possible through use of new system called Roll Barrels. *ALMCO, Queen Products Div., King-Seeley Corp.*
For More Information, Circle No. 20, Page 139-140

ALUMINUM-MELTING FURNACE . . new two-section, dry hearth furnace con-

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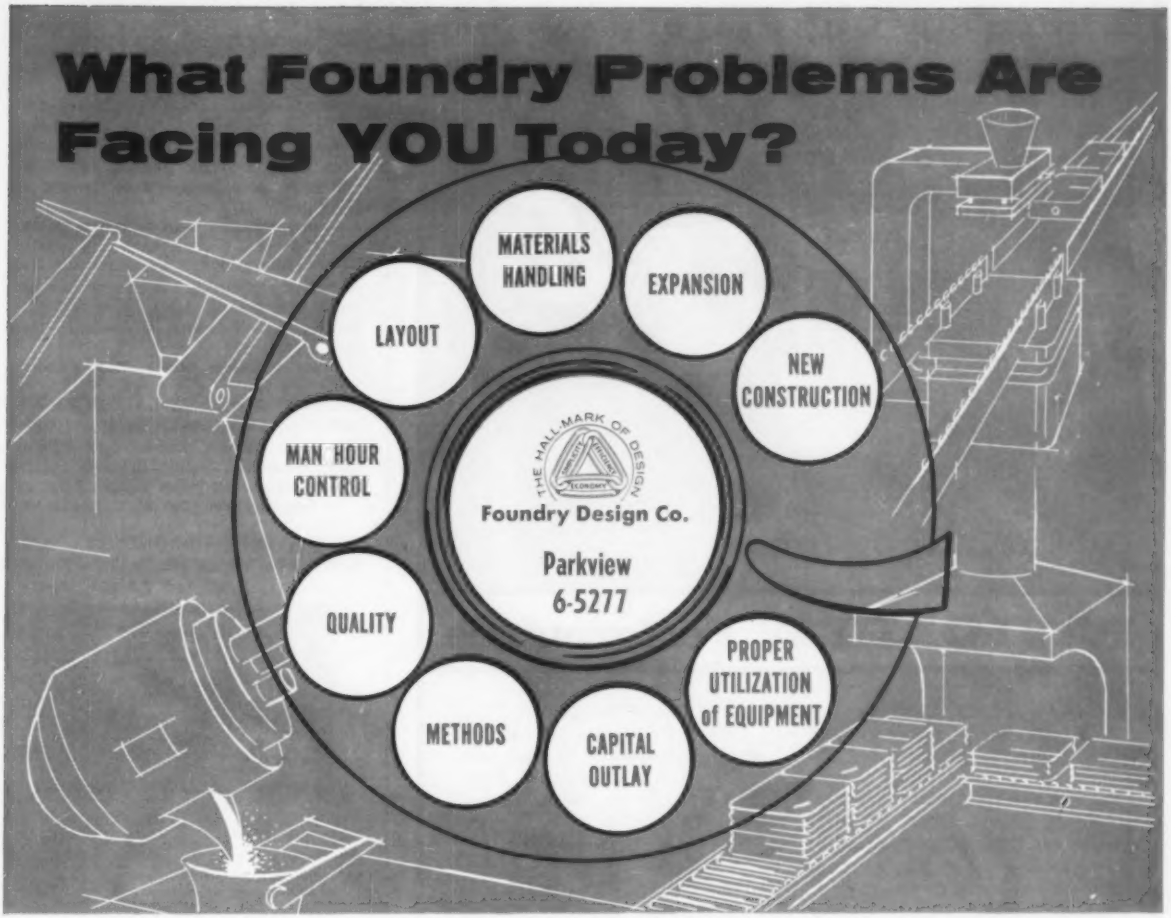

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products and processes

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trols melting of electrical quality aluminum. *Selas Corp. of America.*
For More Information, Circle No. 21, Page 139-140

DIE CASTING LUBRICANT . . has been introduced for plunger lubrication under extreme temperature conditions. *Die Casting "ID" Corp.*
For More Information, Circle No. 22, Page 139-140

BIN VIBRATOR . . . features vise-lock mounting permitting easy portability and quick attachment. Jaws open 2-1/2 in. Delivers 275-lb punch. *Cleveland Vibrator Co.*
For More Information, Circle No. 23, Page 139-140

GRINDING WHEEL BALANCER . . . portable unit balances wheel on grinder. Wheel is balanced in less than 30 minutes. Balanced wheels improve quality of grinding work. *Aero Supply Mfg. Co.*
For More Information, Circle No. 24, Page 139-140

MINIATURE RAILROAD . . . moves heavy loads at 300-fpm speeds. Battery-

powered rail tractor pulls train of two 4-ton cars on 24-in. tracks. *Easton Car & Construction Co.*
For More Information, Circle No. 25, Page 139-140

ELECTRIC CAR-BOTTOM FURNACE . . . holds temperatures to 2000 F with great accuracy. 200 kw unit is recommended for stress-relieving and pre-heating stainless steel valve castings before welding. *Waltz Furnace Co.*
For More Information, Circle No. 26, Page 139-140

GRINDING AND FINISHING WHEEL . . . with two-layer construction permits two different grinding angles so grinding and finishing operations can be done without wheel change. *Bay State Abrasive Products Co.*
For More Information, Circle No. 27, Page 139-140

HIGH-TEMP DIE CASTINGS . . . can be produced with the first die casting alloy which retains mechanical properties through 800 F. Magnesium alloy HM11XA contains one percent thorium and one per cent manganese. *Dow Chemical Co.*
For More Information, Circle No. 28, Page 139-140

ALUMINUM RR BEARINGS . . . are now being produced for test runs in railroad freight car journal boxes. *Aluminum Co. of America.*
For More Information, Circle No. 29, Page 139-140

BLAST CABINETS . . . spinner-hanger cabinets are designed for medium production runs. Features compartment-

Continued on page 10

International MINERALS CHEMICALS

A REPORT TO FOUNDRIES

FROM TOM BARLOW

New hope for overweight castings . . . shed pounds like magic

Sometimes it's hard to figure out where you will end up when you start out. We recently found ourselves with two new products when we only meant to develop one. The one we didn't intend to develop seems to be the most exciting.

How would you like a facing sand that costs no more than an average facing for large castings but which would give such close control over casting dimension that you might take as much as 165 pounds off a 1000 pound casting? You don't believe it? We're doing it! Let us tell you the whole story.

We've been playing with the CO_2 process for some time. We finally came up with a product that had the advantage of good green strength before gassing. We filed for patents on the basis that this product would be of real value for boxes that are hard to draw after gassing.

As you know, a gassed CO_2 core requires good drafts, smooth boxes, etc. They don't all come that way. So with this product, you have enough green strength to draw the core and gas outside the box. Blown CO_2 shells and similar applications came to view. We also filed on the discovery that with this binder we could add up to 1.5% Westonite DS Powder to: 1) cut gassing time in half, 2) stop penetration, 3) improve green strength even further, and 4) improve shakeout. All this seems good if not earth-shaking, but the outgrowth of the idea was really startling.

This is news like "man bites dog". With a slight change in product, we found a way to make skin dried molds like you never saw before! The facing is made of sand plus 3.5% to 5% of Acrasize (the reason for the name will be obvious in a minute) plus 0.5% to 1.5% Westonite DS Powder. Mull for 2 minutes in high speed, or 6 minutes in wheel-type muller (mixers can also be used). The stuff comes out feeling like a good steel sand — about 6 to 7 pounds green strength, high toughness and *no* stickiness. It has a bench life of up to 8 hours if covered with a wet sack in a facing bin. This is rammed over the pattern in the usual way. The pattern is drawn. The mold face is then sprayed with an alcohol wash — high in alcohol, low in wash — and touched off.

The mold is like a rock! The casting is "like a shell". We have worked up to nearly 2000 pound castings and don't know the upper limit. Casting weights have been reduced by between 8% and 16% just by elimination of invisible mold wall movement. We will be glad to show you — in your foundry — something you never saw before.

The core binder — yes, we still think it's the best. We call it "Acrasize, low green" to differentiate it from the facing binder. If green strength, penetration or collapsibility are problems in your CO_2 work, maybe we can help you.

International MINERALS CHEMICALS

Producers of Living Minerals

EASTERN CLAY PRODUCTS DEPT.

INTERNATIONAL MINERALS & CHEMICAL CORPORATION

Administrative Center, Old Orchard Road, Skokie, Illinois • ORchard 6-3000

35-59

Circle No. 150, Page 139-140

How to put the Squeeze on Costly Casting Rejects

use *Famous*

CORNELL CUPOLA FLUX in all Gray Iron and Malleable Foundries

No iron is top quality unless it's clean, and Famous Cornell Cupola Flux is the one scientifically formulated product that increases dirt and slag flow off. Don't accept flux "just as good" —it pays to buy quality—The quality of Famous CORNELL Cupola Flux. It also cleans coke completely, giving you constant carbon content. Cupola maintenance is also reduced when you use Famous Cornell Cupola Flux.

Write for Bulletin 46-B.

No Gamble when you use Famous CORNELL Aluminum, Brass and Copper Flux. Write for Bulletin 46-A.

"often imitated but never equalled"

FAMOUS CORNELL FLUXES

The CLEVELAND FLUX Company

1026-40 MAIN AVENUE, N. W. • CLEVELAND 13, OHIO

Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918

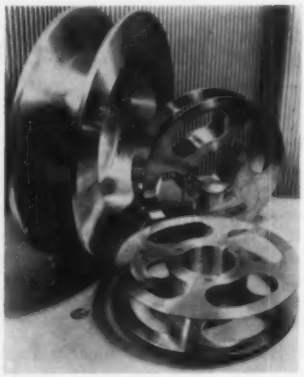
Circle No. 151, Page 139-140

products and processes

Continued from page 8

ed work areas and spinner devices for rotating work. *Wheelabrator Corp.*
For More Information, Circle No. 30, Page 139-140

PARLANTI MOULD PROCESS . . . permanent mold technique producing high



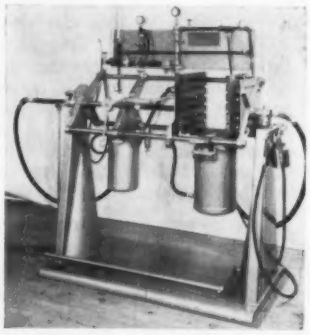
physical and mechanical properties is available for license. *Niforge Corp.*
For More Information, Circle No. 31, Page 139-140

BONDING MORTAR . . . Ankorite 65 has demonstrated outstanding refractoriness and durability in malleable installations. *Harbison-Walker Refractories Co.*
For More Information, Circle No. 32, Page 139-140

SURFACE PYROMETER . . . English-made unit has patented principle which permits accurate temperature measurement regardless of surface roughness and without contact. *Atlantic Pyrometers, Inc.*
For More Information, Circle No. 33, Page 139-140

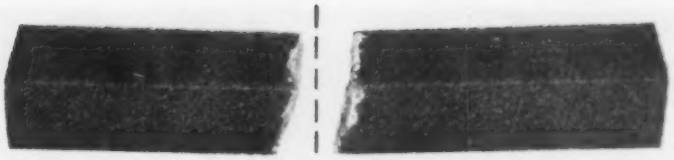
ELECTRIC TRUCK . . for narrow aisle use is available with 4000-lb capacity. *Raymond Corp.*
For More Information, Circle No. 34, Page 139-140

SHELL CORE MACHINE . . . now available in two new models: smaller machine produces cores to 10-in. diam-

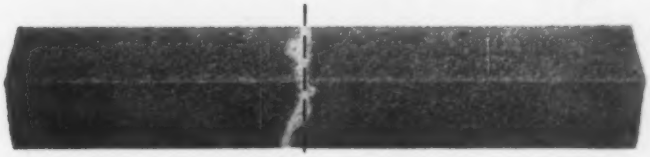


eter, 28-in. long; larger unit produces cores to 30-in. length if cross section does not exceed 40 sq in. *Dependable Pattern Works.*
For More Information, Circle No. 35, Page 139-140

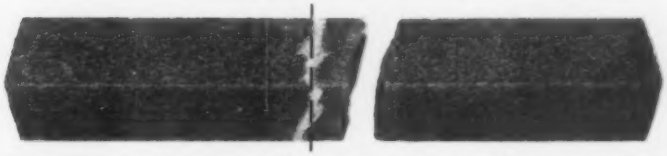
BIN VIBRATOR . . . feeds mulled mix to core blower without sticking or arching of material in the bin. *Eriez Mfg. Co.*
For More Information Circle No. 36, Page 139-140



THE BROKEN ENDS OF A TEST CORE ARE COATED WITH DELTA CORE ADHESIVE



THE COATED ENDS ARE JOINED AND THE CORE ADHESIVE DRIED



WHEN AGAIN BROKEN . . . THE BREAK OCCURS AT OTHER THAN THE JOINT . . .

. . . PROVING THAT THE JOINT IS STRONGER THAN THE CORE WHEN MADE WITH

DELTA CORE ADHESIVE!

Delta Core Adhesives penetrate deep into the core surfaces to produce a weld-bonded joint many times stronger than the core itself . . .

. . . and core sections joined, or mended, with a Delta Core Adhesive are so completely bonded they never break or fracture at the joint.

Delta Core Adhesives are extremely low in gas forming properties which eliminates the danger of blows at a joint. They are completely stable . . . non-reactive with molten metal . . . and because they have a uniform coefficient of expansion with the sand, Delta Core Adhesives will not cause core distortion.

Delta Core Adhesives are available in ready-to-use liquid and paste forms and in easy-to-mix powder form. Each may be applied by dipping or brushing onto the surfaces to be joined then air or oven dried. When dry, Delta Core Adhesives resist moisture pick up.

THREE EASY-TO-USE TYPES
OF
DELTA
CORE ADHESIVES
FOR EVERY NEED AND PREFERENCE

•

READY-TO-USE LIQUID
DELTA GRIPTITE CORE ADHESIVE —
LIQUID

•

READY-TO-USE PASTE
DELTA 200-3X CORE ADHESIVE —
SOFT PASTE

•

EASY-TO-MIX POWDER
DELTA GRIPTITE CORE PASTE
Mix with water to any desired consistency.

OUR 26TH YEAR

DELTA

Working samples of Delta Core Adhesives for test purposes will be sent on request together with instructions for use.

DELTA OIL PRODUCTS CORP.
MILWAUKEE 9, WISCONSIN

MANUFACTURERS OF SCIENTIFICALLY CONTROLLED FOUNDRY PRODUCTS

Circle No. 152, Page 139-140

NATIONAL LP Air CONVEYOR IN ACTION

View from sand bin shows pipe carrying sand to discharge. Note spilled sand, from clamshell operation, at upper left. Air-Conveyor system provides waste-free delivery.

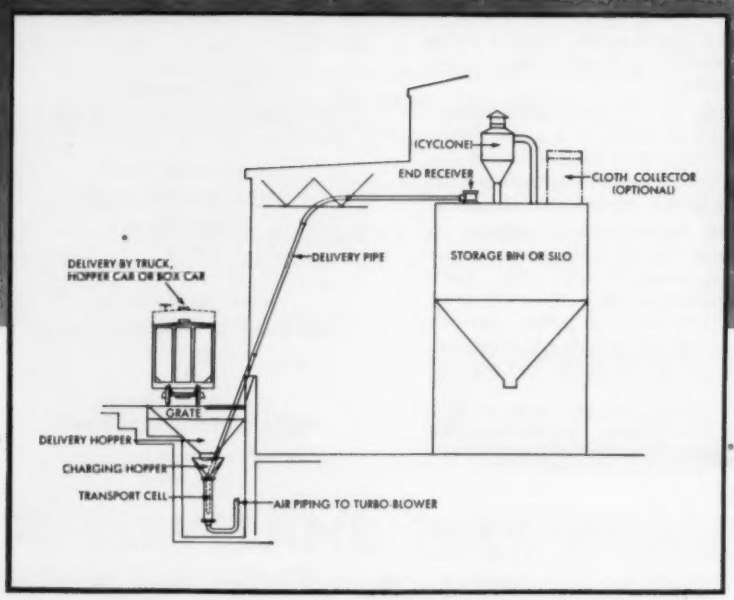
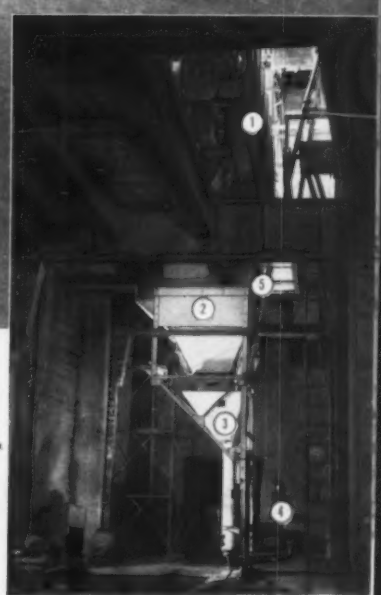


Diagram shows general arrangement of LP Air-Conveyor system for dry sand delivery by truck, hopper car or box car. System also has many uses *within* the foundry.



View from below track showing (1) hopper car, (2) charging hopper, (3) transporter, (4) turbo-blower, and (5) delivery pipe.

How STUDEBAKER-PACKARD saved $12,950 on Sand Delivery Costs

Low cost, low pressure National System slashes maintenance costs, automates dry sand delivery

PROBLEM:

A brisk demand for Studebaker *Larks* had the Studebaker-Packard Corp. foundry at South Bend, Indiana, going at near-capacity. An important sand dryer requiring repair expenditures of $5000 threatened a bottleneck.

SOLUTION:

National recommended the trial of a new low cost, low pressure air-conveyor system for the delivery of new sand. These advantages were cited:

- *Eliminate need for the dryer.* Makes possible dry sand delivery by closed hopper car; eliminating need for dryer and for troublesome paper car covers.
- *Eliminate need for clamshell.* Sand to be discharged direct from car to unit under track, then transported continuously and automatically direct to storage bin, hoppers or belt conveyor.
- *Save time, labor and maintenance* of crane operation. Air-Conveyor is compact, simple and a fully automated system.

As a result of these recommendations, the National LP system was installed.

RESULTS:

During one year of Air-Conveyor operation, Studebaker has:

- Abandoned earlier plans (and need) to overhaul sand dryer. Savings: **$5,000**
- Reduced annual maintenance costs on clamshell system. Savings: **$1,200**
- Eliminated need and labor involved with paper car covers. Savings: **$6,750**

$12,950 represents only an immediate tangible savings to Studebaker. In addition, the Air-Conveyor system now provides all dry sand for core mixers; has reduced manpower requirements; has considerably reduced sand unloading time and contributed to the general improvement of the operation. A second unit, now being installed, will further increase Studebaker's overall savings.

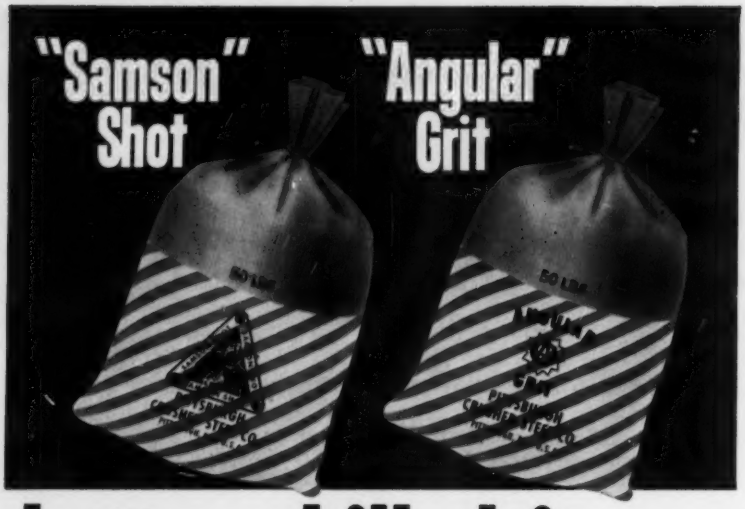
The National LP unit is described at lower left and shown in the photos. It is simple, completely versatile, adaptable to many foundry jobs and occupies but a fraction of the space required for almost any unit it may replace. Its basic cost is considerably less than the amount Studebaker *saved* in one year.

Got a job for Air-Conveyor? Write *National* for further details on either low (LP) or high pressure (HP) Air-Conveyor systems.

IT'S NEW!
IT'S...
ANOTHER!
PROVEN PRODUCT OF THE PRACTICAL FOUNDRYMAN
BY NATIONAL

NATIONAL Air CONVEYOR CORPORATION
A subsidiary of National Engineering Company
630 Machinery Hall Building
Chicago 6, Illinois

Circle No. 153, Page 139-140



better chilled iron abrasives..and why

We have made metal abrasives since 1888. We pioneered their use in place of silica sand for blast-cleaning. We have "grown up" with their expanding use, acquiring unequalled know-how and experience along the way. *No other maker of metal abrasives has an equal experience record.*

Since 1937 we have carried on a continuous program of research for improvement of metal abrasives with one of America's foremost metals research organizations. *No other metal abrasives maker has an equal record of research.*

Ours is the only plant in America using the HOT BLAST MELTING process for production of metal abrasives; this, plus fully automated processing, provides the complete quality control that assures uniformity of chemistry, structure and hardness from one lot to another —assures the user of obtaining the same high performance from every shipment of Samson Shot and Angular Grit.

Experience, research, superior manufacturing facilities make these better chilled iron abrasives cheaper to use than those made to sell at a price.

LEADERS in development of PREMIUM-TYPE ABRASIVES

The two best known names in premium abrasives were developments of two of our subsidiaries. MALLEABRASIVE, the first malleablized type of metal abrasive ever produced, set the pace for development of all other makes of premium abrasives. TRU-STEEL Shot was the first high-carbon all steel shot produced to meet demand for this specialized type of abrasive.

One of these products may do your blast-cleaning job better, and at lower cost. Write us for full information.

PITTSBURGH CRUSHED STEEL CO.

Arsenal Sta., Pittsburgh 1, Pa.

Subsidiaries: The Globe Steel Abrasive Co., Mansfield, Ohio (Malleabrasive)
Steel Shot Producers, Inc., Arsenal Sta., Pittsburgh (Tru-Steel)

Circle No. 154, Page 139-140

Is Your Quality Under Control?

by D. L. LaVelle
American Smelting and Refining Co., S. Plainfield, N.J.

■ From the metallurgical point of view, the quality of aluminum castings can be controlled by the use of foundry practices that will minimize the occurrence of defects in the castings. The more obvious surface defects such as mis-runs, cracks, core-shifts, etc., will not be discussed. We will be concerned only with the internal type of defect due to causes of a more metallurgical nature. It is believed that these defects can be classified into five basic categories.

1) **Non-Metallic Inclusions**
   a. *Dross and Oxide*
      The familiar "hard spots" usually encountered during machining are primarily of aluminum oxide. Molten aluminum should not be mixed with air at any time; to do so introduces the oxides into the metal.
   b. *Flux*
      Powdered fluxes are sometimes stirred into aluminum melts. If sufficient time is not allowed for this flux to separate from the metal it will be poured into the castings. Flux inclusions will usually cause "blooming" of the castings.
2) **Porosity**
   a. *Trapped Air*
      This appears as porosity just beneath the skin of the casting on the cope side, usually associated with the gate area. Most often caused by careless pouring where air and aluminum are mixed together in the sprue creating air bubbles that are carried into the casting.
   b. *Gas*
      Hydrogen gas is formed from the reaction between molten aluminum and moisture. It is soluble in molten aluminum and relatively insoluble in the solid and causes the "pin-hole porosity" revealed on machined surfaces and by X-ray. Minimized by melting oxidizing and not over-heating the melt. Correct by suitable de-gassing.
   c. *Shrinkage*
      Aluminum alloys decrease in volume when changing from a liquid to a solid. This causes porosity in castings when improper or inadequate gating, risering and chilling are used.

Editor's Note: *This article contains highlights excerpted from a talk presented at the* 1959 *Texas Regional Conference.*

Need an oscillating conveyor now?

3 LINK-BELT types cover every need—all are immediately available from stock

Yes, Link-Belt makes a specific type of oscillating conveyor for every type of service.

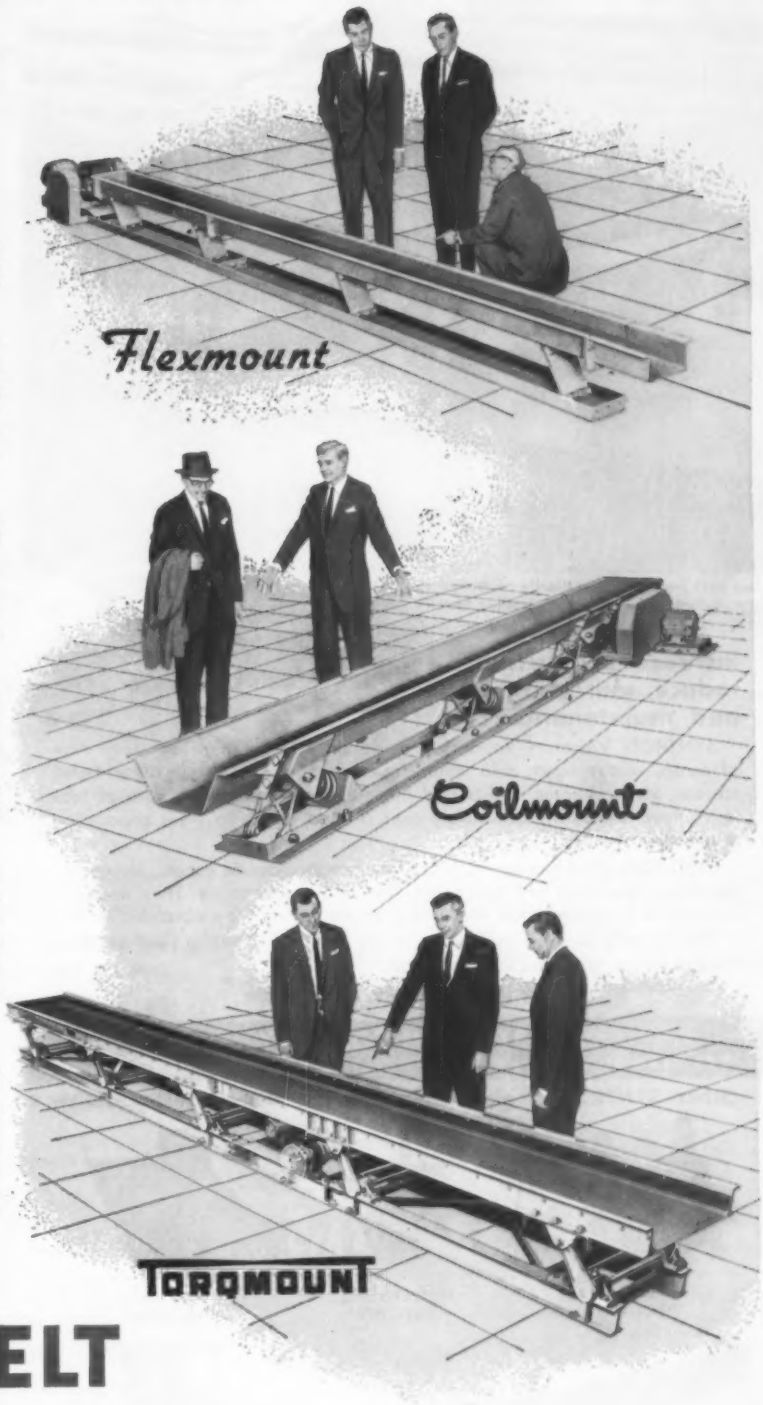
FLEXMOUNT for light-duty service. Ideal for gentle handling up to 25 TPH of 100-pounds-per-cubic-foot material. Widths of 8, 12 and 18 in.—all with 4-in. deep troughs. Flexmounts are pre-engineered — available from stock in 5- and 10-ft. sections.

COILMOUNT for medium-duty service. For applications up to 80 TPH of 100-pounds-per-cubic-foot material. Widths of 10 and 20 in. with 6-in. deep troughs. Available from stock in completely assembled 5- and 10-foot sections.

TORQMOUNT for heavy-duty service. For severe service requirements on installations with capacities up to 350 TPH of 100-pounds-per-cubic-foot material. Widths up to 48 in. with 8-in. deep troughs. Popular 36-in. size stocked.

In every case, Link-Belt POSITIVE ACTION controls the load at all times . . . assures continuous, uniform flow of materials regardless of surges. And each type functions as near to NATURAL FREQUENCY as possible, minimizing power requirements.

For the best in light-, medium- or heavy-duty conveying, call your nearby Link-Belt office or authorized stock-carrying distributor. Or write for new Book 2744 containing complete data on all three types.



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LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs. Representatives Throughout the World. 15.121

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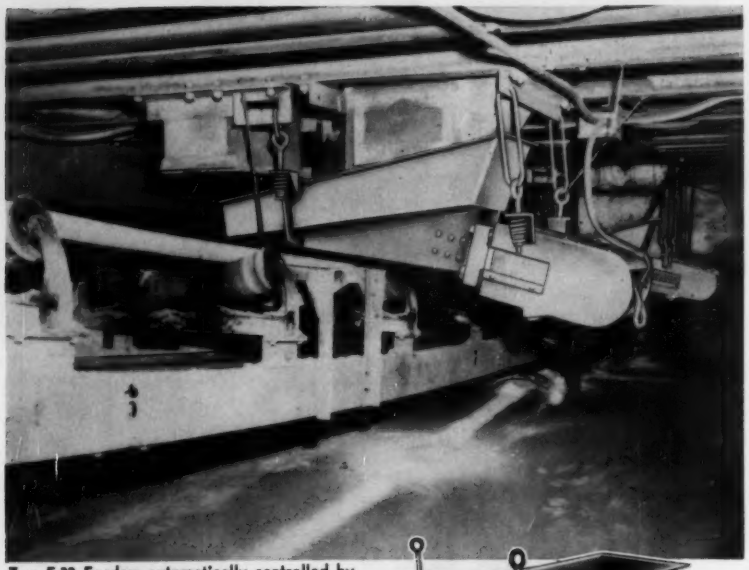
SYNTRON Vibra-Flow
VIBRATORY FEEDERS



Two F-33 Feeders automatically controlled by load cells in a batch bucket, feeding foundry sand onto a belt conveyor.

increase production, reduce material handling and maintenance cost

SYNTRON Vibratory Feeders provide an efficient high capacity flow of scrap, alloys sand, and other foundry materials to conveyor belts, screens, ladle streams, molds and other process equipment. Rate of material flow is instantly adjustable over a wide range to meet production requirements.

SYNTRON Electromagnetic Vibratory Feeders assure longer, more dependable operation with less down time and maintenance. They are constructed to withstand load shock and excessive wear by abrasion.

SYNTRON'S years of experience in the material handling field qualifies them to act on problems large or small.

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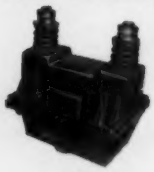
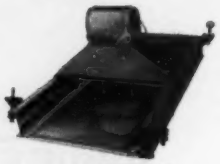
Other SYNTRON Equipment of proven dependable Quality



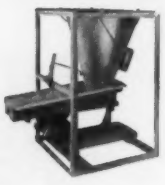
BIN VIBRATORS

HOPPER LEVEL SWITCHES



VIBRATING SCREENS

MECHANICAL VIBRATING CONVEYORS



DRY FEEDER MACHINES

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Russian foundry practice . . .

is quite comparable to current American technology and well worth watching for new ideas. Statements and claims in these items about USSR metalcasting developments appeared in abstracts prepared by the Office of Technical Services, U. S. Department of Commerce, Washingon, D. C.

■ Aluminum addition to the stream of molten steel as it goes into the mold is most effective way of attaining necessary aluminum concentration for deoxidation.

■ Higher mechanical properties and resistance to cracks in steel castings are ensured by the disorderly spacing of sulfide impurities. This arrangement is effected by adding 400 grams of aluminum per ton to the pouring stream as it goes into the mold.

■ USSR foundrymen have designed a cupola which saves on coke consumption by introducing natural gas through burners located above the tuyeres.

■ A machine has been built that makes the cope, drag and cores all simultaneously. Core box is so located that drag can be lowered onto half core box holding the core in such a way as to position it properly in mold. Mold is rotated 180 degrees, closed with cope and poured.

■ Uniform mixtures of metals and metallic compounds which will not form liquid solutions with each other are being formed by adding one alloy (in powdered form) to the base metal (in liquid form) and solidifying the mix while applying sonic or ultrasonic oscillations. An alloy of tungsten carbide and lead has been formed this way.

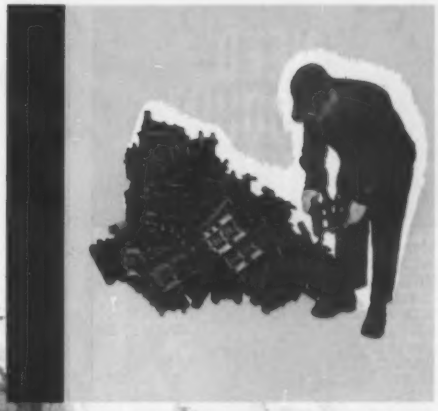
■ Accurate sand molds are being pressed at the rate of 250 per hour in the USSR and Czechoslovakia. Pressures from 50 to 2000 tons are being developed in hinge-lever presses. Another operation combines pneumatic vibration with pressure. Crawler tractor chain links and gears are being cast in the molds.

■ Fluid flow in gating systems is being studied by using cork particles in gasoline. An especially efficient slag trap has been designed with this technique.

■ Productivity is being increased in foundries by ramming molds and cores with sand-blasting and sand-jet methods. Sand and water-glass mix is chemically hardened.

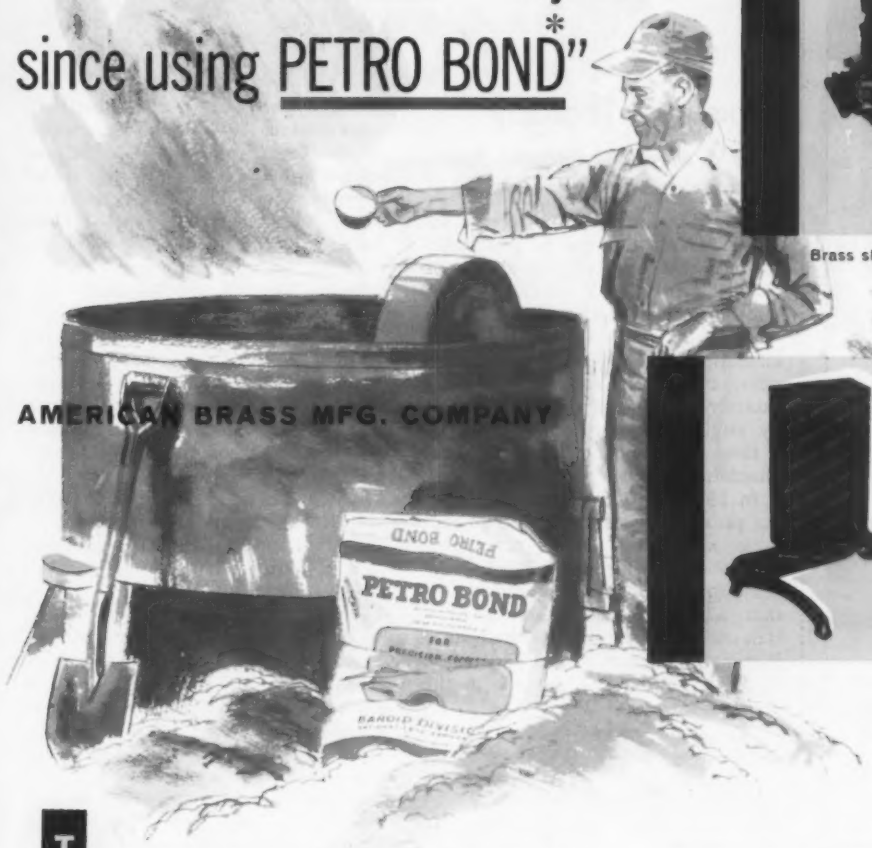
■ Green sand stack molds are being made by pressing patterns simultaneously into the top and bottom of flask containing sand.

..."less than 2% rejects since using PETRO BOND*"



Brass shakeout of brass plumbing fixtures.

Brass plumbing fixtures in finish.



The American Brass Manufacturing Company of Cleveland, Ohio were able to lower their percentage of casting rejects to less than 2% . . . when they used PETRO BOND as their formulated sand-bonding agent. This is an enviable net end result . . . one desired by many foundrymen.

YOU too can obtain these same results . . . once PETRO BOND becomes your sand-bonding agent.

Castings made with PETRO BOND are better because they provide smoother finish . . . more faithful reproduction of the pattern . . . sounder castings . . . closer tolerances . . . denser surface . . . plus less porosity.

PETRO BOND produces precision castings with conventional foundry equipment. Let PETRO BOND prove its cost-cutting advantages to you. It will cost you nothing to find out.

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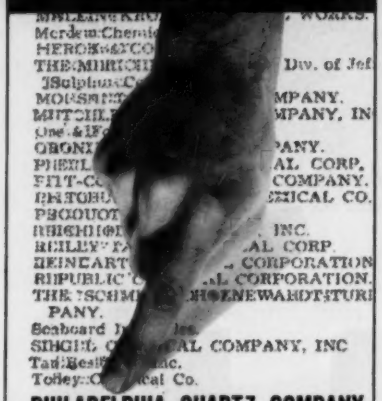
NEED SODIUM SILICATE?



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Convenient availability coast to coast from plants located in Anderson, Ind.; Baltimore, Md.; Buffalo, N.Y.; Chester, Pa.; Jeffersonville, Ind.; Kansas City, Kan.; Rahway, N.J.; St. Louis, Mo.; Utica, Ill. and from associate companies: Philadelphia Quartz Company of California—Plants located in Berkeley and Los Angeles, Calif.; Tacoma, Wash. National Silicates Limited, with plants located in Toronto and Valleyfield, Canada.

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When it's silicate service you need, contact PQ.

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TRADEMARKS REG. U.S. PAT. OFF.

PQ SOLUBLE SILICATES

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Circle No. 158, Page 139-140

the SHAPE of things

safety, hygiene, air pollution

by HERBERT J. WEBER

Aluminum Therapy

Is It a Medical Escape from an Engineering Problem?

From time to time we receive inquiries about the use of aluminum therapy in the prevention of silicosis. Does it work? Is it quackery? Is it sensible to control the effect of silica dust on the lungs by the deliberate inhalation of another dust—aluminum, or is it more sensible to prevent excessive concentrations of silica dust by engineering and other methods?

Here are some of the facts about aluminum therapy.

In 1936 two Canadians noted that the presence of small amounts of metallic aluminum almost completely prevented siliceous material from passing into solution. Later it was shown that a relationship exists between reduction of solubility of free silica by aluminum powder and a decrease in the occurrence of damage to the lungs by silica dust.

Animals were then exposed to sufficient concentrations of silica dust to cause silicosis but at the same time the animals were given daily inhalations of aluminum powder. No silicosis developed.

These experiments were later checked and confirmed by other investigators.

Hence it was natural to see what effect the inhalation of aluminum dust would have on patients suffering from silicosis.

In 1944 a group of 34 patients with silicosis were treated by being given freshly ground aluminum dust to inhale.

Improvement was noted in about half of the patients, but the testing procedure was questionable.

In 1948 Dr. Berry of the University of Colorado was the first to test aluminum therapy on men under *scientifically controlled conditions.*

He selected 35 silicotics for experiment. Twenty-six of this group received aluminum therapy and nine breathed pure air as controls. All of the subjects thought they were inhaling aluminum dust. A part of Dr. Berry's report follows: "Of the treated group, 22 considered themselves to have improved; 4 considered themselves to have been unchanged and none believed that they were worse. It was the impression of the investigator that 15 had remained unchanged, and that 8 had become worse. Three men, members of the treated group, undoubtedly became better. It is not possible to attribute all the improvement to aluminum, as each one of these men prior to treatment had been working in the dusty atmosphere of a hard rock mine, but during and following treatment had found other employment. It is well known that removal of a silicotic from a dusty atmosphere will by itself produce considerable subjective improvement.

"All members of the control group considered themselves improved. It was the impression of the investigator that 6 were unchanged and 3 were worse.

"During the course of the study, there has been no evidence of aluminum toxicity. This is of interest because there are several reports in the literature concerning possible toxic effects of aluminum dust on the lung. In all of the reported cases, the aluminum concentration has been exceedingly high in the atmosphere breathed by the affected persons but there is as yet no convincing proof that aluminum was responsible for the changes observed . . . . the high incidence of symptomatic improvement in the control series indicates that future work with aluminum in the treatment of disabling silicosis must be properly controlled in order that its worth may be proved . . . . in the aluminum-treated group, no objective changes were observed which could be convincingly attributed to the metallic therapy."

Dr. O. A. Sander, an expert in the field of industrial chest diseases, while admitting the modifying effect of aluminum dust, is of the opinion that foundry atmospheres already contain modifying dusts, e.g., iron oxide, and therefore he does not recommend the use of aluminum dusting for foundrymen.

Industrial hygienists prefer to prevent silicosis by controlling the silica dust and do not regard aluminum therapy as a substitute for dust control.

That is about where the matter stands today!

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Circle No. 159, Page 139-140

product report . . .

Electric arc-air blast melting principle solved the dilemma facing the Automatic Transportation Co., Chicago, of scrapping versus alteration of twenty 4000-lb cast iron lift truck counterweight castings worth a total of $6000. The castings could be used by removing a section, 4x3x30 in., from each one.

First efforts at removal of the section by means of drilling and oxyacetylene cutting took 24 hours and resulted in expensive drill bit breakage. At that point, the Arcair Co., Lancaster, Ohio, was called in.

An Arcair Model H-3 Torch completed the job in just 6 hours per casting. The process combines electric arc and ordinary compressed air.

Technique for Arcair Torch cutting operation was mastered in only 15 min.

Aerospace Casting Needs

■ "Aircraft and missiles in the next 10 year period will need materials with improved high temperature properties (up to 5000 F), radiation resistance, emissivity properties and impermeability for protecting oxidizable materials." So says the 1959 Annual Forecast of Trends and Requirements prepared by the Aerospace Industries Association.

In a 50-page report to the Government and industry they warn that "the use of castings will reduce, and in many applications weldments will be used in place of castings." In the next 10 years the aerospace complex will require steels with 300,000 psi yield strength. Needed will be fabrication techniques and equipment which place the metal as close as possible to its final configuration. Precision casting may well be the answer to this need.

For a copy of this elucidating report write Aerospace Industries Association, 7660 Beverly Boulevard, Los Angeles.

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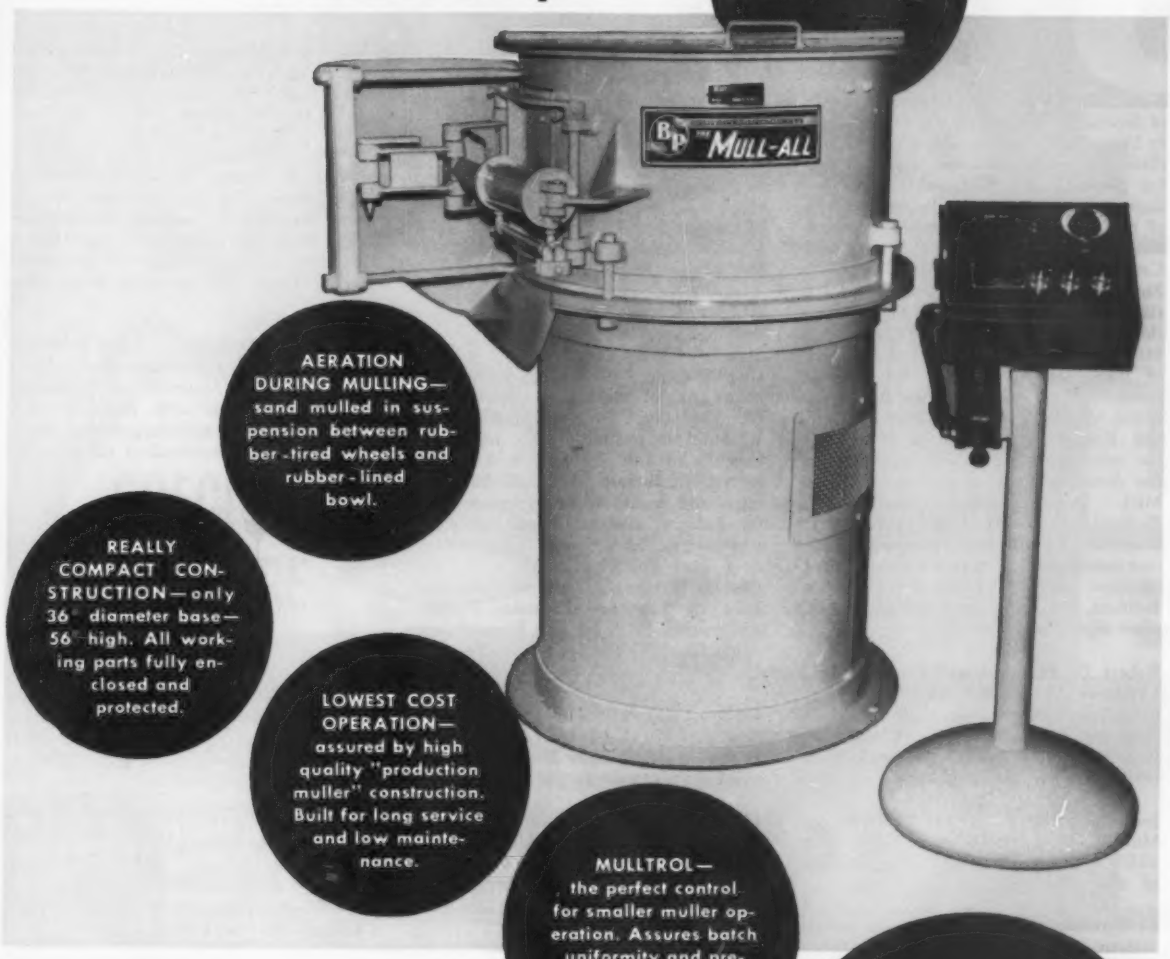

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Circle No. 160, Page 139-140

E. H. Weak

H. J. Roast

P. J. Keeley

K. M. Smith

C. K. Donoho

S. A. Glueck

let's get personal

Elmer E. Braun . . . is now manager of ferrous operations for Central Foundry Div., GMC. Braun, who was formerly divisional works manager, is responsible for plants in the Saginaw, Mich., Defiance, Ohio, and Danville, Ill. plants of the division. Other changes following the consolidation of the Fabricast and Central Foundry Divisions: **George A. Zink,** formerly general manager of Fabricast, continues as manager of the Fabricast plants in Bedford, Ind. and Jones Mills, Ark., and also serves as manager of light metals programs for Central Foundry Div. **Carl A. Koerner** is now director of sales and engineering for Central Foundry Div. and is responsible for sales and engineering activities in the divisions plants located at Saginaw, Mich., Defiance, Ohio, Danville, Ill., Bedford, Ind. and Jones Mills, Ark. **Edgar A. Wondracheck,** formerly Fabricast manufacturing manager, is now plant manager of the Fabricast plant in Bedford, Ind., with the Jones Mills, Ark. plant reporting to him.

Robert D. Bradford and **Edward McL. Tittmann** . . . have been elected as executive vice-presidents of American Smelting & Refining Co. **Charles F. Barber** and **Forrest G. Hamrick** have been elected as vice-presidents.

Jack Dimond . . . vice-president of Mid-Continent Steel Casting Corp. since 1950 is now executive vice-president of the Shreveport, La. company.

D. Russell Smith . . . has been named eastern sales representative for Tonawanda Iron Div., American Radiator & Standard Sanitary Corp. He was formerly with North Attleboro Foundry, North Attleboro, Mass. for 20 years.

Frank Clifford . . . is now sales representative for H. G. Enderlein Co., Philadelphia. He formerly served in the same capacity for Olney Foundry Div., Link-Belt Co., Philadelphia.

Kenneth M. Smith . . . has been promoted from staff engineer, general office, Caterpillar Co., Peoria, Ill., to maintenance engineer at the Peoria plant. He is chairman of the AFS Safety, Hygiene and Air Pollution Control steering Committee.

Leslie A. Andrus . . . vice-president, Wheelabrator Corp., Mishawaka, Ind. and **Richard A. Brackett,** executive vice-president, Spencer Turbine Co., Hartford, Conn., have been named as reservists in the National Defense Executive Reserve of the Business and Defense Services Administration. Both are members of the Foundry Equipment Manufacturers Association and would represent the foundry equipment industry in case of a national emergency.

Charles F. Witters . . . has been named manager of distributor sales, Delta Oil Products Corp., Milwaukee. **Nard V. Stapf** is technical sales representative, Delta Oil Products, in Ohio and Kentucky. **Robert W. Gall** has been appointed technical sales representative for Indiana, eastern Illinois and southwestern Michigan.

Charles Menzer . . . is now works manager for Superior Aluminum Foundry, Ridgewood, N. J. He was formerly with Alloy Steel Castings Co., Southampton, Pa.

Duncan A. Currie . . . is now general manager, H. C. Macauly Foundry Co., Berkeley, Calif. **Victor Henderson** is now plant superintendent.

Harold J. Roast . . . former AFS National Director and an Honorary Life Member, and **Eugene H. Weak,** have been appointed as special service associates for Westover Corp. & Associates of Milwaukee.

Philip J. Keeley . . . recently became vice-president, Northern Bronze Corp., Philadelphia. He is a director of the AFS Philadelphia Chapter.

Frank J. Coolbaugh . . . has been named president, Climax Molbdenum Co., Div., American Metal Climax, Inc., succeeding **Weston Thomas,** now executive vice-president of parent company.

Alexander Szabo . . . with Pangborn Corp., Hagerstown, Md., since 1955, is now an abrasive engineer. **Robert D. Rose,** formerly with Industrial Metal Abrasive Co., has also been named abrasive engineer. Both will headquarter in Detroit.

Samuel A. Glueck . . . has been appointed as assistant to the president of H. Kramer & Co., Chicago. For the past 25 years Glueck has been with the Federated Metals Div., American Smelting & Refining Co.

Charles K. Donoho . . . American Cast Iron Pipe Co., Birmingham, Ala., has been appointed to represent AFS on the A.S.T.M. Committee D-5 on coal and coke.

Joseph L. Mullin . . . has retired as vice-president of the American Manganese Steel Div., American Brake Shoe Co. after 45 years with the Amsco division. He will continue as a consultant to Amsco and American Brake Shoe Co.

Donald H. Ambrose . . . has been appointed foundry superintendent, Rosedale Foundry & Machine Co., Pittsburgh, Pa. He has been with Rosedale since 1947 serving as metallurgist and assistant foundry superintendent prior to this promotion.

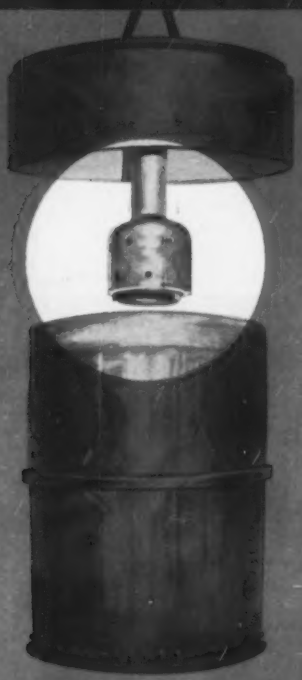
obituaries

G. Dixon Shrum, 63, executive secretary and treasurer of the Foundry Facing Manufacturers Association since 1947 and a prominent Pittsburgh attorney, died June 12.

He was graduated from the University of Pittsburgh Law School in 1925 and was president of the school's General Alumni Association for two terms. He was a past president of the Allegheny County Bar Association and a member of the Pennsylvania Bar Association, American Bar Association and American Law Institute. Shrum was also active in boys' activities.

Glenn E. Cramer, 58, professor of engineering, University of Illinois, Navy Pier Branch, Chicago, died July 5. Prior to joining the University of Illinois faculty in 1947 he had served for 21 years as superintendent of alloy foundry, American Manganese Steel Div., American Brake Shoe Co., Chicago Heights, Ill.

DUCTILE IRON



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Write for your copy of our new brochure, "Plunging Sil-Mag Alloys."

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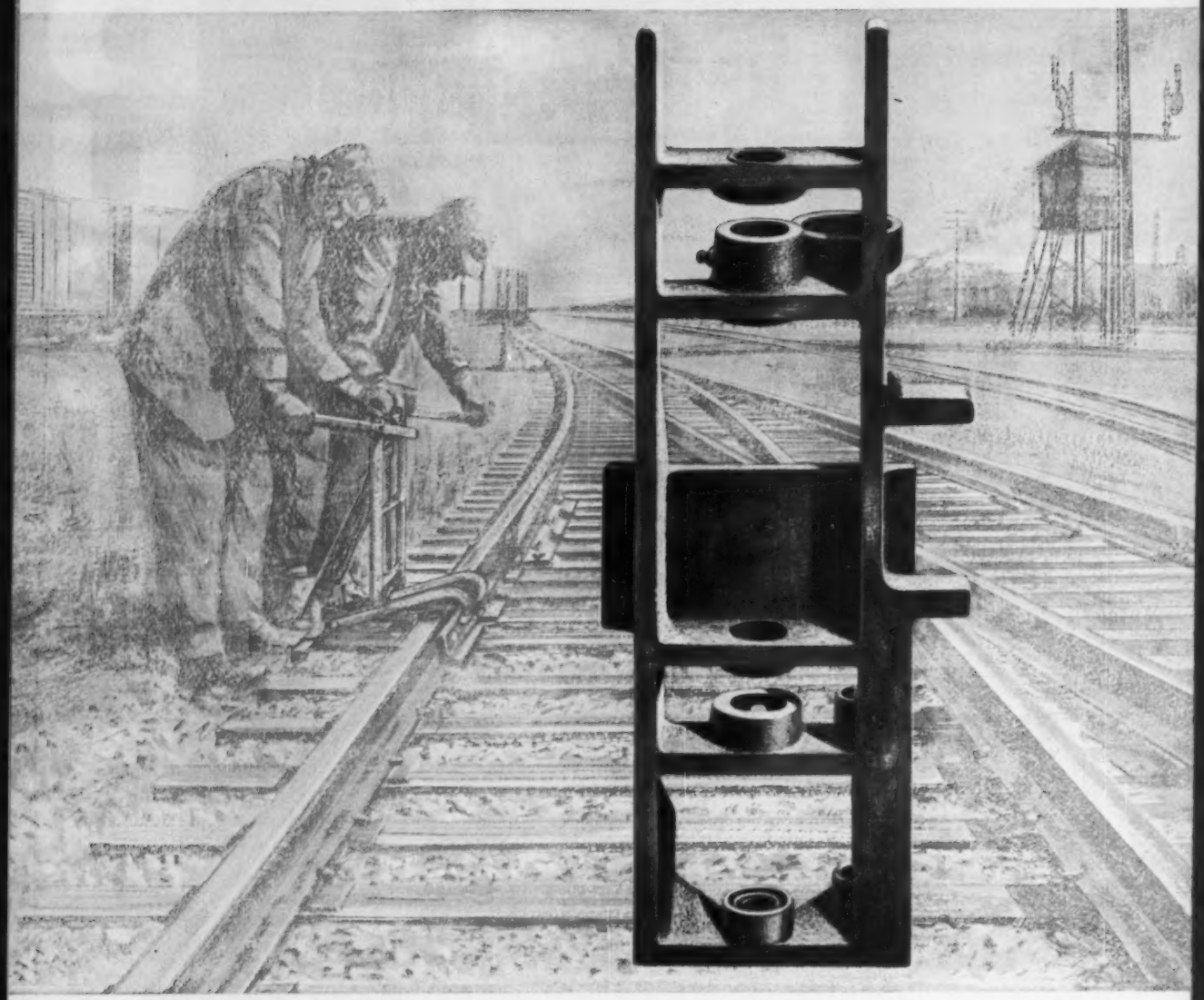
How the Foundry Industry serves America . . . #2 of a Series



SINGLE IRON CASTING REPLACES WELDMENT . . . REDUCES COST BY 66⅔%

This power track drill frame was originally produced as a weldment. It required cutting, positioning, assembling, welding and inspecting 23 separate parts. It was a major manufacturing headache in every way, and the scrap ran high.

Foundry engineers redesigned the part as a one-piece malleable iron casting at one-third the cost, plus additional savings in final machining operations.

This is impressive proof that modern iron castings deliver outstanding performance and impressive economies when specified by the industrial designer.

Hanna Furnace is proud to be part of this great industry and will continue to provide foundries with all regular grades of pig iron . . . malleable, foundry, Bessemer, intermediate low phosphorus, as well as HANNATITE® and Hanna Silvery.

Facts from files of Malleable Founders Society

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Circle No. 162, Page 139-140

BLOWING STEEL WITH DRY AIR

by J. B. Bridges *and* G. L. Meeter
Cameron Iron Works, Inc., Houston, Texas

This is a short paper on the results of using dry air for mixing and removing carbon from hot steel. Over 23 heats have been stirred with dry air with no harmful effect and 12 heats have been blown with air or a mixture of air and oxygen to remove carbon. Results:

1) Carbon removal rate is less than that for oxygen, 2) There is no large pickup of nitrogen from the air, and 3) the temperature generally drops during the course of the blow.

AIR DRYER In order to get dry air, a type of dryer in use at Cameron to dry the air for blast cleaning equipment was utilized. This dryer was designed by Cameron Plant Engineering and cost in the neighborhood of $400. The air is led into a chamber containing alumina pebbles which absorb the moisture. When a dew point of 10 F or above is reached, the cover is taken off the drying chamber and absorbed moisture is driven off with heat from a gas flame.

AIR-OXYGEN MIX In order to check the effect of mixing oxygen with the air, a manifold was designed and placed at the exit of the drying chamber. Any combination of air and oxygen could be used to blow the heat. The apparatus was first used to blow dry air through the steel for mixing purposes and to help remove dissolved hydrogen from the bath. The mixing action was good.

Silicon was removed on the average of 0.06 per cent. This loss was due in part to the reaction with oxygen dissolved in the bath as well as oxygen from the air blow as the test was run immediately after slag-off when the bath was deoxidized with 75 per cent ferrosilicon.

CARBON REMOVAL The use of dry air for reducing carbon in the heat was tried next. Steel was melted, heated to a temperature high enough so the carbon-oxygen reaction could occur and then blown. Three heats were blown with 100 psi air through a 1/2-in pipe. The higher rate of carbon removal was on a starting temperature of 3100 F. Generally, the higher the starting temperature the faster the carbon removal.

Three more heats were tried using a lower air pressure with a 1-in. pipe. The higher pressure was the most effective. Finally, five heats were blown using a mixture of air and oxygen. For fast carbon removal, relatively high pressure air was necessary.

Table I

Stirring with Dry Air	
Heats	23
Pressure	25 lb
Time	2 min
Lance	1 in.
Temperature	
Average Drop	3 F.
Max. Drop	40 F.
Silicon	
Average Drop	0.06%
Max. Drop	0.16%
Nitrogen Pickup	Not Detected

The two main elements removed in our tests were carbon and silicon. Manganese and chromium contents were unaffected. Phosphorus was not affected greatly, probably because the bath was quite hot during the blow. Nitrogen, as on the stirring experiments, was not greatly changed. Temperature changes during the blow showed the exothermic nature of the oxygen addition as there was less temperature loss when oxygen was added to the air.

DIFFICULTIES Using air for blowing the heat was difficult for three reasons. First, steel splashed up on the door and doorjambs where it froze forming a crust that tore brick out of the jamb area when pushed back into the bath. Second, slower carbon removal with air meant a longer heat time during the oxidizing period. Third, if the electrodes were not raised away from the splashing metal, carbon was picked up. On a heat of stainless, 0.05% C was picked up in five minutes.

Recommendations for the use of dry air for removing carbon would include:

1) Use a dryer in the air line to keep out excess moisture. Dry out the alumina when the dew point shows a moisture content of above 10 F.
2) Blow the heat at as high a starting temperature as feasible with furnace operations.
3) If oxygen is available, try to combine with air so neutral nitrogen helps keep bath temperature down and carbon is removed at an economical rate.

Editor's Note: *This article contains highlights excerpted from a talk presented at the* 1959 *Texas Regional Conference.*

In the interest of the American foundry industry, this ad (see opposite page) will also appear in

Steel
Iron Age
Modern Castings
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Circle No. 162, Page 139-140

HIGH FLYING

QUALITY CASTINGS

Author Richard L. Hanson, Research Foundry Engineer for Solon Foundry Inc., Solon, Ohio, tells how his company is helping keep pace with the casting requirements of the vast aerospace complex.

Convinced that the nation's most discriminating buyers—the aircraft and missile industries—would beat a path to their door, Solon Foundry, Inc. decided several years ago to rise above conventional casting practices.

In achieving their purpose, Solon is contributing significant quantities of aluminum and magnesium alloy castings to the guided missile and jet aircraft projects of over a dozen companies. Some of these castings meet critical specifications in wall thickness to as low as 0.070 in. with an over-all tolerance to ±0.010 in. Many pump housing castings, having a wall thickness of 0.25 in. and over, withstand liquid pressure testing from 0 to 3000 psi in just a few seconds. Such specifications are vital to efficient performance at supersonic speeds.

Solon Foundry realizes that the metalcastings industry must develop new materials, methods and means to meet the challenge of the coming Space Age. The instrument housing circling the globe within the United States' satellites, Explorer I and III (Fig. 1), were cast by Solon Foundry—also several important components in the missile and jet power plants manufactured by Aerojet-General Corp. and Rocketdyne Div., North American Aviation, Inc.

Fin tips (Fig. 2) for the Chance-Vought F8U Crusader jet plane are cast of a magnesium alloy with a wall thickness of 0.100 in. This casting is also held to an over-all contour of plus or minus 0.010 in.

Quality Control A Must

SOM Precision Industries, Division of Solon, was alone selected to conform to fixture standards for the cockpit canopy (Fig. 3) of the new supersonic "Vigilante" jet attack aircraft produced by North American Aviation, Inc. The canopy, comprising two aluminum alloy hollow castings, is held to an over-all tolerance of plus or minus 0.015 in. This twin-jet plane carries a total of 85 Solon Foundry castings.

Experience has proved that castings destined for

U.S. Army Photo

EXPLORER III
Fig. 1 . . Author R. L. Hanson inspects cast magnesium alloy instrument housing now in orbit as part of satellite Explorer III shown on left.

U.S. Army Photo

finished wing tip for F8U Crusader plane. Close-up view of a thin-walled casting and its shell core are shown below.

supersonic flight must have virtually every fabrication operation controlled within exact specifications. Missile and jet aircraft castings can be no better than your quality control system.

Solon's sand laboratory tests every mix of core sand for permeability, moisture content, hardness, tensile properties and gas evolution. Core and pattern storage rooms are temperature controlled the year round.

Eighty per cent of Solon's production is in castings so critical that they require 100 per cent inspection. Solon's x-ray inspection facilities include a 140 kv and a 250 kv unit. Some critical castings are inspected by micropolishing in addition to x-ray and zyglo. The United States Air Force, Navy and many other customers inspect and approve these testing facilities periodically for certification.

Sectioning at least one in every 25 castings leads to close control over surface finish and dimensions on pump housing castings. These castings are submitted to no less than 27 different x-rays—a total exposure time of 46 minutes. The "Vigilante" cockpit castings receive 100 per cent x-ray and 100 per cent zyglo inspection.

Code Every Casting

Each casting at Solon is coded so that any production discrepancy may be quickly traced. All records pertinent to each individual casting are available on a moment's notice—exact pouring temperature, mold and core properties, metal heat, etc.

All sixteen 500-lb crucible-type furnaces have temperature control within ten degrees in the range of 1300 to 1450 F. Any deviation beyond ten degrees results in gas pickup or shrink porosity; below, misruns and cold shuts develop. Alloying elements and impurities are often held to closer tolerances than are normally permitted in prime ingot specifications.

New Resin Binder

Perhaps one of the greatest single factors contributing to the quality control of critical castings comes from a new acrylic resin core binder.

This binder provides a quality core and maintains critical standards both on the inside and outside surfaces of castings.

Many castings, such as the five-stage pump housing for Thompson-Ramo-Wooldridge, are "all core" castings for which even the molds are produced from core mixes and baked like inside cores. Twenty-seven cores, three of them plaster, go into this pump-housing fabrication (Fig. 4). Critical fixturing and drying periods limit production of these core-mold units.

Acrylic resin is a noncuring plastic core binder material which hardens when water contained in the mix evaporates. No attempt is made to reclaim core sand at Solon Foundry. Critical aircraft and guided missile castings require such quality control that reclamation is inadvisable. So fresh binder and sand go into each mix.

A typical core sand formulation is 300 lb of No. 80 AFS sand, 9 lb of acrylic binder, 0.25 per cent graphite and 1 lb of water.

Cores Are Versatile

Added strength comes from 1/2 to 1 per cent south-

Fig. 3 . . This new supersonic twin-jet, the Vigilante, has 85 Solon castings aboard. Casting in insert is cockpit canopy comprising two hollow aluminum castings.

Fig. 4 . . This intricate all-core pump assembly demonstrates success with cores and core molds.

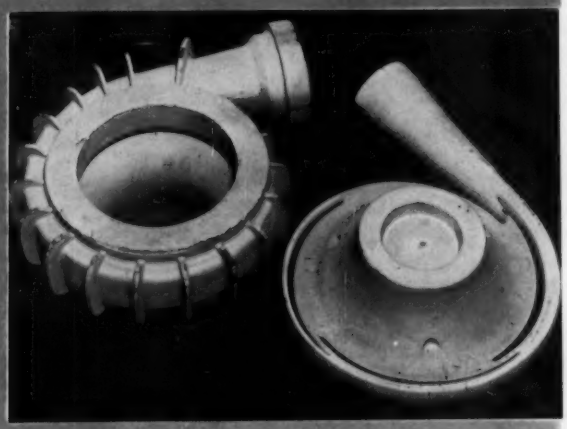
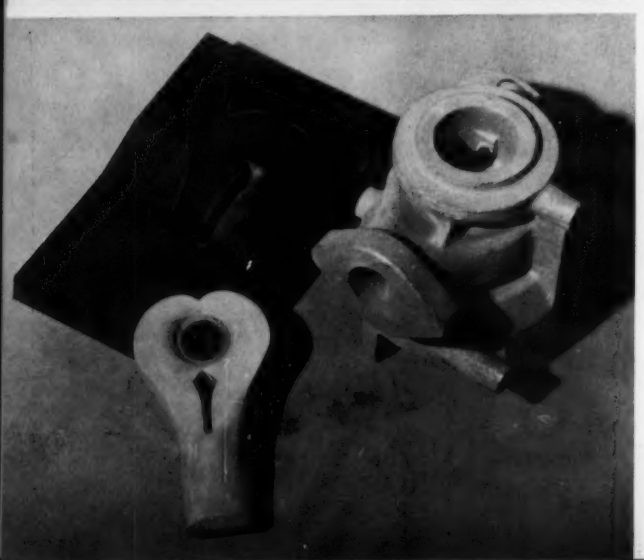


Fig. 5 . . Plaster cores are used for forming complex internal cavity needed for this pump.

Fig. 6 . . Back draft and straight draws are no problem when using rubber core boxes for plaster cores like the one shown below for a pump.



ern bentonite and 1-1/2 per cent ground silica flour. Southern bentonite helps eliminate core swelling by reason of its extremely low water absorption rate. Nonorganic silica flour evolves no gas and raises green strength beyond one pound. This additive offers green strength comparable to that obtained with more bentonite as well as increased scratch hardness. Bentonite's effect in reducing baked core tensile and scratch hardness tends to be offset by silica flour.

There is no danger of losing strength or surface hardness through air drying green cores, since moisture removal is the mechanism for setting. The resin binder will air-set, but slowly. For speedy setting, Solon bakes cores at 425 F in gas-fired ovens. Cores bake with equal effectiveness in either direct or indirect fired ovens. *Cores may also be set by hot air gassing as in the CO_2 process.*

Average size cores are baked for 1-1/2 hours; tolerance for "overbaking" is extremely good. Maximum baked physical properties may be achieved under a wide range of time and temperature conditions. Moisture elimination is all that's required to attain full strength of acrylic cores.

With no change in binder volume due to volatilization, condensation, oxidation or polymerization during baking, dimensional stability is close to perfect. Collapsibility is excellent; complicated castings clean quickly in knockout. Baked cores flow quickly from castings when using pneumatic hammer knockout.

Close control over all ingredients in the core sand mix contributes to the 125 rms and finer microfinishes attained on special surfaces. Lack of gas evolution and shrinkage in core mixes contribute greatly to metallurgical soundness and close dimensional tolerances.

Gypsum Plaster for Cores

Solon has invested over two years experimentation into perfecting the use of gypsum plaster as a core material. Plaster is useful when particularly high specifications must be met. Coremaking plaster is gypsum plaster modified with foaming agents, chilling agents and accelerators. Plaster cores can produce as low as a 43 rms microfinish and tolerance within 0.010 thousandths of an inch on aluminum castings weighing up to 60 lb (Fig. 5). When high finishes and close tolerance demand, plaster cores are substituted for sand cores in green sand molds.

Plaster insulating properties allow a lower pouring temperature which in turn yields higher physical properties and finer grain structures in castings. Plaster cores account for high molten metal fluidity, superior casting finish and closer dimensional stability. These cores possess good permeability and do not crack under thermal shocks. Collapsibility is good compared to conventional investment-type materials.

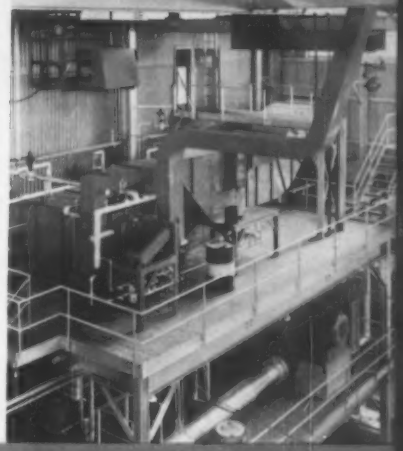
Rubber core boxes are used exclusively in fabrication of plaster cores (Fig. 6). Back draft and straight draws offer no problem in these boxes.

Future Bright

The foundry industry future hinges upon its ability to meet the challenge of increasingly critical specifications in casting fabrication. For foundries willing to work out quality control systems needed to meet these specifications, the future looks bright, indeed. ■ ■ ■

DON'T ALLOY YOUR IRON WITH WATER

by F. L. RIETVELD
Surface Combustion Corp.
Toledo, Ohio



1

Your casting quality is not under control if tons of unregulated water are riding the air blast into your cupola melting zone every day.

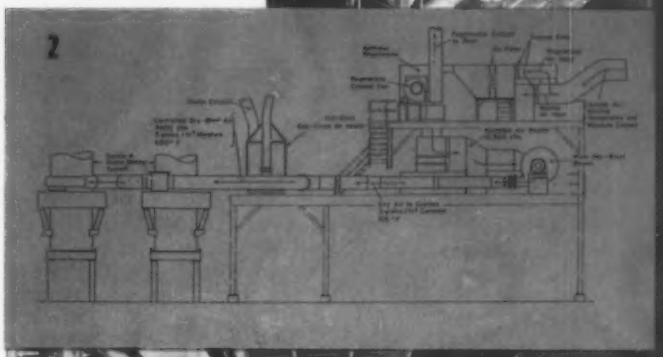
You may wonder why a foundry bothers to remove water from its cupola blast air. A 72-inch cupola blower delivers 9200 cfm of air containing 11 grains of moisture per cu ft on a humid day. This means 900 lb of water going into the cupola every hour. And water is always an undesirable alloying addition to cupola iron—it lowers metal temperature and metallurgical quality.

The quality and production advantages of a low and constant moisture level in blast air have been long known and well documented. However, the degree to which such control is achieved and the particular arrangements for controlled reduction in air moisture content vary widely.

Many foundries, specializing in heavy, thick-section castings, add booster coke charges to the cupolas when a drop in melt temperature indicates increasing moisture in the blast air. Thin-section castings, on the other hand, are more sensitive to moisture level in the cupola blast; excessive metal shrinkage and cracked castings in high summer humidity are familiar occurrences to many foundrymen.

Most producers of relatively thin malleable castings and piston rings, where the penalty for excessive blast moisture is far higher, have thus sought means of controlling blast moisture automatically under all weather conditions.

The Midwest's newest malleable iron foundry has engineered unusually close control over moisture content of the blast air fed into its twin cupola installation.



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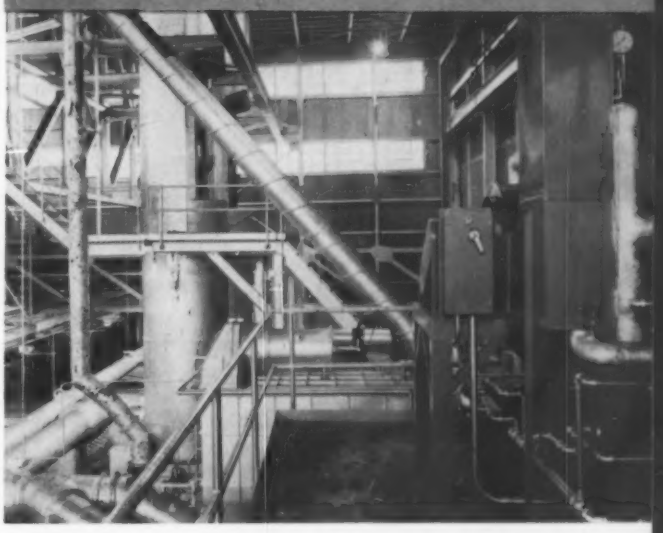

3

Moisture Automatic Control

This new melting facility is one of the first duplex malleable foundries to include an automatic moisture-control unit as an integral part of the original blast system. Many foundries have successfully installed moisture-control units in existing blast lines. Such installations must compromise with existing conditions so they have often resulted in high cost, inconvenient location of the units and, most importantly, an insufficient degree of control.

In comparison, the new foundry's moisture-control system, as shown in the schematic diagram Fig. 1, maintains blast moisture content at 3 grains per cu ft automatically under all outside temperature and humidity conditions. Compare this with 11 grains present on a humid summer day.

Chemical-Type System

An automatic moisture-control system may be either a refrigeration or chemical type. The chemical-type system in Fig. 1 was selected for the new malleable iron foundry because:

1) Chemical-type units had proved their value in foundry operations for some time.
2) Chemical-type units are capable of both withdrawing and adding moisture to the input air. Because 3 grains per cu ft is a relatively low moisture level, the moisture-control unit removes moisture most of the time. However, during very cold winter days humidity can be sufficiently low to require addition of moisture to the blast air.

(*Continued*)

3) Air is intentionally discharged from the moisture-control unit at the comparatively high temperature of 105 F. This practice puts a smaller air heating load on the air heater feeding into the cupolas.
4) Extremely close control over moisture content of the cupola air is achieved.

The chemical-type moisture-control equipment in Fig. 1 is a Kathabar system. This system has separate regenerator and conditioner (air washer) units which are mounted on two elevated floor levels adjacent to the cupolas. Both the regenerator and air-washer set less than 50 ft from both cupolas. Such proximity minimizes duct lengths and fan power required to maintain proper flow.

Moisture-Control System

Outside air is drawn in from the right in Fig. 1 through preheat coils and air filters into the regenerator on the upper level and the air washer below. Moisture is removed from (or added to) the filtered air in the air washer chamber as the air passes through a flooding spray of a hygroscopic lithium-chloride solution. Density and temperature of the chemical solution determine the degree of moisture removal in the air washer. By automatically controlling both density and temperature, air discharges from the washer with constant moisture content.

To maintain a constant density in the moisture-absorbing solution, a small quantity of the solution is automatically pumped to the regenerator unit on the upper floor level and sprayed over low-pressure steam coils. The resulting increase in temperature makes the solution give up moisture in a controlled amount to a scavenger air stream. The scavenger air in the regenerator never reaches either the plant interior or the air discharged to the cupolas. As shown in Fig. 1, part of the outside air is diverted to the regenerator air input as the scavenger stream. After absorbing the required moisture in the regenerator, the air is exhausted to the roof in a separate duct.

The 105 F air output of the washer is then fed by the main blast blower either directly to the operating cupola or through the gas-fired air heater. The air heater raises the blast air to 750 F and feeds it back into the main duct line to the cupolas. The heated dry air comes to the cupola at a rate of 7400 cfm and a temperature of 750 F.

Blast air enters each cupola on alternate days by shutting gates in the blast line to the inactive cupola. Blast input is divided into two streams on opposite sides of the active cupola.

In Fig. 2 the Kathabar regenerator unit is shown on the upper level, with the regenerator exhaust duct rising to the roof at the upper right. The inlet air duct extends to the plant wall on the right of the regenerator. In the lower right of Fig. 2 the main blast blower and cylindrical output duct to the cupolas appear in front of the air washer.

The duplex cupolas are shown in Fig. 3 to the left of the regenerator in the foreground. The cylindrical duct slanting upward from behind the regenerator on the right carries the air heater exhaust to the roof. Blast air ducts to the cupolas are at the lower left. ■ ■ ■

5

by F. R. Black/Technologist
Baroid Div., National Lead Co.
Houston, Tex.

Many modern foundry methods are designed to free the foundryman from the problem of controlling temper in green sands. One of the newer methods, now in extensive use, eliminates temper control by creating a moisture-free green sand. This emancipation involves the use of an oil swelling binder, a catalyst, a readily available petroleum oil, and one of a variety of domestic sands.[1]

The first step in preparing a water-less molding sand mix is the proper choice of ingredients. Some rigid technical limitations on materials are suggested in the following paragraphs.

First, select the proper binder. This binder must form a gel to produce a bond with the suggested oils. Such a requirement eliminates most of the water sand additives. All clay has some adsorbing tendencies toward oils but not usually enough to produce a bond in a foundry sand. Some pure hydrocarbon derivatives form a gel-like structure with oils; but this bond is weak and temperature sensitive. A compound which will establish a bond with oil similar to a water clay bond was patented by E. A. Hauser, U. S. Patent No. 2,531,427, Nov. 28, 1950. This material is bentonite which has been chemically changed to make it organophilic (organic attractive).

This material forms, with the proper oils, a green sand having excellent mold properties. Suitable oil binders can be distinguished by preparing batches of green sand and determining their molding properties (as described later in this report).

The second ingredient to obtain is a proper oil. Choice of the proper oil has been one of the greatest hindrances to the preparation of a successful moisture-

. . advantages of moisture-free green sand molding

1 Sands can be selected almost exclusively to fit the casting finish desired.

2 Low gas evolution reduces permeability requirements of mold.

3 Dense molds permit accurate control of dimensional tolerances.

4 Cleaning costs decreased by excellent peel and mold atmosphere control.

5 Binder does not evaporate so mix can be re-used extensively.

free sand. Perhaps the principal reason is the foundryman's familiarity with a separate class of oils—the core oils. Green sand oils do not polymerize or "set up" on heating, like core oils.

Motor lubricating oils are also unsatisfactory, because they possess in some degree a detergent which will inhibit bonding action. A third class of oils does form a bond. A comparison of the green strengths of sands prepared with various types of oils follows:

TABLE 1

Oil Type	Green Strength (psi)
Core Oil	6.9
Acceptable Oil	12.6
Light Motor Oil	4.7

Acceptable oils are petroleum based oils of low viscosity, used principally for industrial cooling and lubricating. A general specification based on extensive development is:

SUS at 100 F	Approx. 100
Aromatic content	10 — 20%
Naphthenic content	35 — 45%
Paraffinic content	40 — 50%
Viscosity index	Less than 75

Few foundries are equipped to evaluate the listed physical and chemical properties of oils but local petroleum dealers will coordinate the above specification with their products. In this manner you can locate a proper oil. The final proof of an oil is the preparation of a successful molding mix.

Next, consideration of a proper sand is in order. Sands of various grain size and shape are being used successfully. Most important, the sand should be dry and have a low clay content. Clay in amounts greater than 1/2 to 1 per cent presents the problem of discharging its adsorbed water in the hot mold.

The per cent moisture adsorbed by the clay will vary from 6 to 12 per cent depending upon temperature and humidity. Sand selected should have a low water content (1/4 to 1/2 per cent). Sand with a water wet surface is difficult to bond and will promote casting defects in an oil sand similar to those caused by water in a water-clay bonded sand.

With little or no water present in a sand, permeability becomes a minor problem. Permeability control is needed in a water-based green sand to vent the large quantity of vapors evolved at the mold innerface. This vapor diminishes greatly in an oil-wet sand for two reasons: 1) the oil which evaporates by contact with hot metal is much higher in molecular weight than water and gram for gram will produce a lower volume of vapor; 2) low heat conductivity of the oil* prevents all but the oil near the mold metal contact from reaching a vaporizing temperature. Therefore, the need for high permeability and close permeability control in the oil-wet sand is reduced.

Selection of a sand grain size can then be tailored to the finish desired on the casting. Sands of 150 to 180 gfn meet with success in oil-wet sand mixes. Some low permeability is still needed to discharge the small amount of contact vapors. The workable limit of permeability is reached in only the finest sands commercially available (Fig. 1).

In practice, sands of round grain classification,[2] are preferred. Angular and sub-angular sands give excellent mold strengths but require high molding energies. If a choice is economically possible, select a round grain sand.

The final ingredient needed to compound a moisture-free green sand is a catalyst. This is a polar molecular substance which disperses the particles of binder. Dispersion allows the oil-binder gel to form more readily than if only muller action were used. Evidence appears in Fig. 2. Note that the addition of over one per cent catalyst has little value. The catalyst commonly used is a low-grade industrial methyl alcohol. A certain caution should be excercised in the use of these volatile materials. An open muller should be used and smoking should be prohibited in the immediate area.

Mixing Methods

The proper ingredients have now been selected to prepare a moisture-free green sand. Now let's combine these materials into the green sand mix.

The following sequence of addition is in general use:

1) Sand and binder are placed in a clean, dry muller and blended.
2) Oil is sprinkled over the dry mix and mulled.
3) The catalyst is added and mulling continued until the desired bond is formed.

This procedure was devised on the theory that a more complete blend of sand, oil and binder is possible under conditions of least mix strength. After thoroughly blending these three materials, the catalyst

ALUMINUM Machine casting above was made at Elmira Pattern Works, Elmira, N.Y. The surface finish of the casting reflects sand grain size used. Castings after shakeout from moisture-free sand mix are remarkably clean. These aluminum tool housings made by Atlas Foundry, Chicago, have a steel insert.

is added to promote the desired strength in the least possible time.

The term "muller" is used herein to indicate a device which will give an intensive pressure-shear action. Such an action is necessary to a greater extent in oil-wet sands than in simple water clay synthetic sands.

The times involved in the mixing cycle vary considerably with the type of muller and production conditions of the individual foundry. A time of 1/2 to 1-1/2 min. is required in a low-speed muller for blending the sand and binder. Three to five minutes will suffice for distributing the oil in the same muller. The time of mulling with the complete mix present can vary from 9 to 15 minutes or longer.

Figure 3 summarizes the strengths developed in a low-speed muller over a time period. One sample mulled for two hours showed only a slight change in mix strength over that found after 20 minutes. Therefore, overmulling presents no problem with the moisture-free sand mix.

The AFS approved sand-testing methods help control the mix. Each size and shape sand requires varied amounts of bond to create the desired molding properties. That the binder to sand ratio varies is seen in Table 2.

TABLE 2 — Bond Required for Various Sands

Sand	Per Cent Binder Required To Attain Green Compression Strength 8 psi	10 psi
152 grain fineness (round grain)	3.4	3.6
133 grain fineness (round grain)	3.0	3.3
90 grain fineness (round grain)	3.0	3.1
125 grain fineness (sub-angular)	3.0	3.1

In changing the binder to sand ratio, also change the oil so as to maintain an oil to binder ratio of 2 to 3.5. A typical 130 gfn round grain sand yields its optimum molding properties with the following mix:

100 lb sand
3-4 lb binder
2-3 lb oil
1/2 lb catalyst

Measured properties of a successful mix appear in Table 3.

TABLE 3 — Properties of Typical Oil-Base Green Sand Composition

3-½% binder
2% petroleum oil
¾% methanol
93-¾% washed and dried round grain sand (gfn-135)

Green Properties		
Compression strength, psi	—	12
Permeability (clock) No.	—	14
Deformation, in./in.	—	0.009 to 0.015
Mold hardness of 3 ram specimen	—	84

Hot Properties

AFS test procedure — soaking time, 4 minutes
Compression strength, psi — 26
Deformation, in./in. — 0.03

An initial mix should be prepared with the above mix ratios. After sufficient mulling, measure its green compression strength. If the strength is higher than needed, dilute the mix with clean sand. If the strength is low, continue with an additional 5 minutes of mulling. Should the compression strength be still low, add binder plus appropriate oil and catalyst and mull. If the mix strength is still low, the properties of the ingredients should be rechecked.

Mold hardness is also a criterion for a proper moisture-free sand mix. The hardness by machine ramming should exceed 80 green hardness number.

Physical Mold Conditions

The action of sand in flowing and compacting is for the most part identical with the oil-bentone or water-clay system. Round grain sand of 120 gfn has a flowability number of 85 to 88 with an oil-bentone bond. Some features of the physical mold condition of the oil bond sand should be cited.

The first is the inability to over-ram this sand. Most of the common casting defects attributed to over-ramming of a water-sand are eliminated for oil sands simply by the absence of the water. Other casting defects which are attributed to silica expansion are also virtually unknown in an oil-based sand.

Secondly, patching is easy in oil sand because there is no mold drying. Liquid parting agents should not be used with oil-wet sand. Finally, the prepared molds have an almost indefinite shelf life. A properly prepared mold will not sag or weaken during storage.

Pouring temperature for oil-wet molds can often be decreased from that used for water-clay bonded

BRASS Plumbing fixtures were cast in moisture-free sand mix by American Brass Manufacturing Co., Cleveland.

MAGNESIUM Castings with unusually thin walls can be made by Curto-Ligonier Foundry, Melrose Park, Ill., in moisture-free sand.

molds. This property is related to the heat transfer characteristics of oil when compared with water. With a slow heat flow through the mold, the metal remains fluid over an extended period. Higher fluidity within the mold feeds thin sections. The long heat retention and slower solidification have been credited with producing sounder castings.

Thermodynamic characteristics of the mold may require a change in shakeout schedules. The oils have a flash point of 300 to 500 F. If shakeout takes place before inner-mold temperatures are below the oil flash point, burning will occur. Although burning is localized and produces nontoxic smoke, it should be avoided. The loss of burning oil will weaken the mix and produce a venting problem in the foundry building.

Casting Finish

Castings after shakeout are remarkably clean. With a virgin mix a thin layer of burnt material may adhere loosely to the casting surface. This material can be blown off or removed by light fiber brushing. With used mixes the peeling is excellent.

Casting surface presents a finish reflective of the sand grain size used. Mechanisms related to moisture, expansion and oxidation which tend to mar surface finish are limited in the oil-wet sand. Certain advantages are often found in having a reducing atmosphere within the mold.[3]

Seacoal, oil and other organic materials are added to the mold for this purpose. With an organophilic clay-oil bonded mold, these additions are unnecessary because small amounts of carbon and carbon derivatives are freed by the degeneration of the oil and clay organic at the mold innerface. This carbon produces a reducing atmosphere within the mold.

This moisture-free sand has successfully produced high quality aluminum, brass and bronze castings. As the weight and pouring temperature of the casting increases, the mix must, in some cases, be altered. This is done much as in water sands. That is, flowability and permeability may be changed by altering

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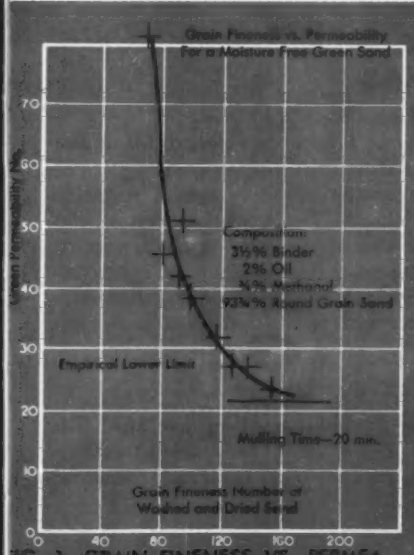


FIG. 1. GRAIN FINENESS VS. PERMEABILITY FOR A MOISTURE FREE GREEN SAND

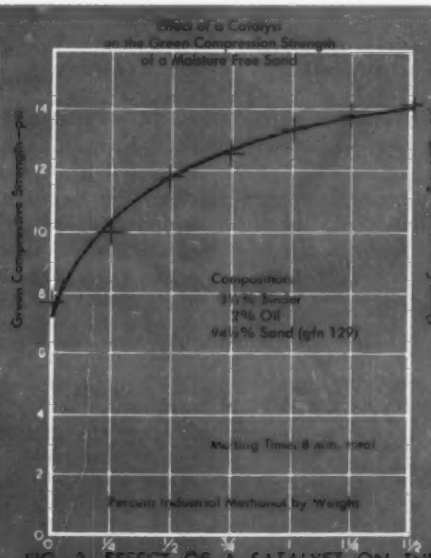


FIG. 2. EFFECT OF A SATALYST ON THE GREEN COMPRESSION STRENGTH OF A MOISTURE FREE SAND

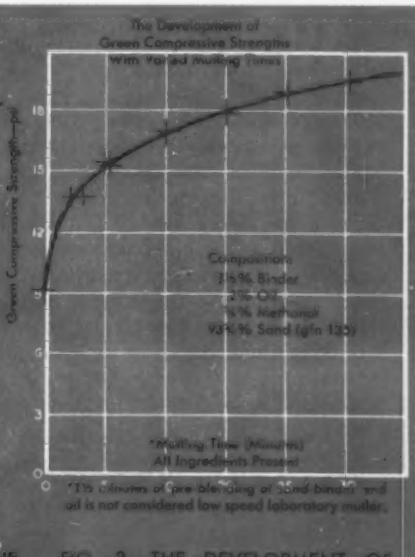


FIG. 3. THE DEVELOPMENT OF GREEN COMPRESSIVE STRENGTHS WITH VARIED MULLING TIMES

tax consultant .... talks to .... foundry operator about DEPRECIATION

Irving Elbaum is a CPA particularly versed in the tax problems facing foundry operators today. One of these is the dilemma of depreciation. To straighten out some of the confusion on this subject Elbaum sits down and has a friendly chat with one of his clients – a foundryman who is trying to make ends meet and still stay competitive by using modern equipment in his shop. The conversation between Irving and his client J. B. runs along like this . . .

Irv, the word "depreciation" seems to have different meanings to different people in our metalcasting industry. Would you be good enough to explain the accountant's definition?

Well, J. B., the accountant and, for that matter, the income tax agent as well, understands depreciation to be a reasonable allowance for the wear and tear of property used in a business. Generally, the factor of obsolescence is also included in any estimate for depreciation. This is understandable when one stops to consider that the probable useful life of a piece of equipment can be appreciably shortened by changes in economic conditions, loss of trade, new inventions, prohibitory laws, etc.

In that case, Irv, if no cash outlay is involved in depreciation, isn't it in effect just a bookkeeping entry?

True, it is a bookkeeping entry. However, it is an extremely important one. Even though no cash outlay is involved for any given year's depreciation, it is vital to realize that records of the business should provide for depreciation. The day will come when that 20-ton crane of yours will have to be replaced and there may not be enough cash left over from the profits of the business to buy a new one. Although this item of depreciation may be considered invisible in any one year, you certainly know it isn't invisible when the cash has to be laid out for the new crane after the old one has served its purpose.

O.K., but let's go into some detail as to how the entry of depreciation helps to provide for the replacement of my new cupola dust collector.

I thought that might be bothering you. Now, J. B., let's suppose that your business showed a profit of $25,000 for the year 1958, without considering the item of depreciation. You might therefore consider that you increased your net worth by that amount of money. Whereas, actually you might have increased your net worth by only $23,000, assuming there was $2000 of depreciation which you had neglected to record on your books. You would be rudely awakened when some day you had to buy a new dust collector to replace the old one. If you hadn't held back enough cash from the profits of the years during which the original equipment was being depreciated, you would find yourself faced with a need for sufficient cash when the time came to buy new equipment. Naturally, this could be a great economic shock to your business.

Well, then, how do I go about determining the expected life of a dust-collector system?

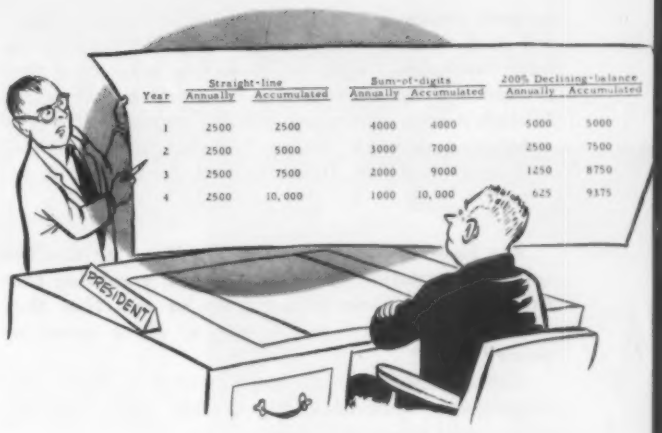
As you might expect, there are several ways in which this can be done. The manufacturer of the equipment can give you his estimate of the longevity of the system. The Internal Revenue Service by means of its Bulletin "F" indicates that the expected longevity of a dust-collector system is approximately twenty years.

Does this mean I'm obligated to use the estimated longevity figure that the manufacturer gives me or the figure that Internal Revenue suggests?

No, absolutely not. In the final analysis you are the one who will make the decision as to the number of years over which you feel it is fair and reasonable to write off the cost of the machine—less salvage value, of course. Only you know the exact conditions under which the machine will be working.

You just mentioned the expression "salvage value." What does that mean, Mr. C.P.A.?

Salvage value means the amount you expect to recover from the sale of the machine at the end of its useful life. This has to be a guess; but try to make it an educated guess rather than picking a figure out of the blue.



Year	Straight-line Annually	Straight-line Accumulated	Sum-of-digits Annually	Sum-of-digits Accumulated	200% Declining-balance Annually	200% Declining-balance Accumulated
1	2500	2500	4000	4000	5000	5000
2	2500	5000	3000	7000	2500	7500
3	2500	7500	2000	9000	1250	8750
4	2500	10,000	1000	10,000	625	9375

It seems I've heard my friends talking about different methods for computing depreciation.

Right, there are at least three popular ways to compute depreciation: 1) the straight-line method, 2) the sum-of-the-years-digits method, and 3) the declining-balance method.

1) *The straight-line method is predicated on the assumption that wear and tear are uniform during the useful life of the equipment. Therefore the cost of the item less its estimated salvage value is depreciated in equal amounts over the estimated useful life.*
2) *The sum-of-the-years-digits method is based on the assumption that the depreciation is higher in the early years and lower in the later years of the life of a piece of equipment. The years-digits method works as follows: different fractions are used each year against the original cost, less salvage value. The numerator of the fraction represents the remaining useful life of the item each year, and the denominator, which always remains the same, represents the sum of the digits of all the years corresponding to the estimated longevity. For example, if a core blower has an estimated life of four years the denominaor of the fraction would always be 10, since the sum of 4 and 3 and 2 and 1 equal 10. For the first year four-tenths of the cost (less salvage value) would be depreciated, three-tenths in the second year, etc.*
3) *The declining-balance method uses a depreciation base which is lowered each year by the amount of the depreciation deduction and a steady rate is applied to the balances that result. Under Federal Income Tax provisions this declining-balance rate may be as high as 200 per cent of the straight-line rate.*

Whoa, slow down, Irv. Can you show me that comparison in writing?

Sure. I have it all worked out right here on this sheet of paper. This tabulation shows for each of the three methods the annual depreciation charge as well as the accumulated depreciation up to the end of any given year. It was first assumed that some material handling equipment cost $10,000 and had a negligible salvage value. It was also estimated that the useful life of the items would be four years.

Note that under the straight-line and sum-of-the-digits methods the accumulated depreciation is $10,000 at the end of the fourth year. Whereas under the 200 per cent declining-balance method the accumulated amount is only $9375. The balance of $625 can be handled in one of two ways. The income tax law allows a taxpayer to switch from the declining-balance method to the straight-line method at any time without the consent of the Commissioner of Internal Revenue. It would be a wise idea for you to switch from this declining-balance method to the straight-line method after the end of the third year. Another alternative would be to depreciate the group in the amount of $1250 in the fourth year of the group's life if the assets were abandoned by the end of that year.

I suppose there are other useful purposes served by depreciation records.

You bet there are, J. B. Records of depreciation are invaluable in cases of loss, where you are trying to prove to the insurance company what the values of the damaged items were. Also, personal property tax and sales tax audits are greatly facilitated by bringing into play accurate and up-to-the-minute depreciation records. When either the entire business is to be sold or when a given piece of equipment is to be sold it sometimes is vital that the prospective purchaser know what the cost, the annual depreciation, the accumulated depreciation and the salvage value factors are.

Every so often, Irv, I like to figure my break-even point. Naturally, in order for me to be able to do that I must know my overhead. Is it really important for me to include depreciation as an item of overhead?

Absolutely. Although depreciation is in a sense invisible, it is also insidious. If you allow yourself to be deluded by the fact that it is not important to include depreciation as an item of overhead because

no cash outlay is involved, you will be fooling yourself to the extent that you will be understating your total overhead. Depreciation merely acts as a convenient method for reducing the profit on the books to such a level that when the day comes that a new piece of equipment has to be purchased there will be enough funds in the business to be able to do so.

We have two fork-lift trucks. Must we use the same depreciation method for both, assuming that they are both new in use with us and that they have an estimated useful life of three years or more?

Not at all. You may depreciate one under one depreciation method and you may depreciate the other under an entirely different one.

Suppose I had a bad year in my business in 1958 and did not choose to deduct depreciation. Would I be allowed to deduct twice the normal amount in 1959?

No, you can't get away with that. The law is so worded that the deduction for depreciation is limited to the amount that was allowed or allowable. Since depreciation for 1958 in your case was allowable, even though you chose not to take that deduction, you would never be able to recover the depreciation for that year...

You know, a competitor told me recently that he figures depreciation on his shell molding machine exactly to the day. Must I do the same thing?

Not necessarily. If you'd like you can do this. Any equipment bought during the first half of the month can be considered to have been bought as of the first of that month; any equipment bought during the last half of a month can be considered to have been bought as of the first of the next month. Some firms handle additions and subtractions of equipment that occurred during the year by assuming they took place as of the mid-point of the calendar year, namely July 1.

I've been hearing quite a bit about some new income tax benefits in connection with the depreciation deduction. Would you review the salient points?

Surely. I'd be glad to. The new tax law gives a business the option of using a one-shot benefit which amounts to a flat 20 per cent of the cost of the item. The item must be personal property which is used in a business or for income-producing purposes. The equipment must have an estimated useful life of six or more years and have been acquired after Dec. 31, 1957. The items can be new or used. The flat 20 per cent is figured on the cost, no provision having to be made for the estimated salvage value. The maximum amount allowable is $10,000, or $20,000 for married taxpayers filing a joint return, in any one year.

Does this new depreciation replace the speedy methods we used on last year's tax return?

*No. The new flat 20 per cent is in addition to any regular or speedy method. However, it is important to recognize that the speedy methods you have been using cover **new** property that has an estimated longevity of **three** or more years. And that it is either personal or **real** property. Notice how much more limiting the new provision is.*

Suppose I want to use the 20 per cent provision on a centrifugal pump which I bought Nov. 1, 1958. Must I prorate the 20 per cent, since I only had the pump for two months in 1958?

Again, no. This flat 20 per cent deduction is allowed even if you had the pump for only one day during the year. As a matter of fact, the 20 per cent can even be deducted if the pump were sold during the year.

Could I see an actual illustration of these new pointers? How about jotting down an example.

Be glad to, J. B. Now suppose your firm bought some cleaning equipment on July 1, 1958, with an expected life of eight years and costing $4000. If the straight-line method is used and the equipment was second hand, your foundry would be entitled to $1000 as its first year's depreciation deduction. Here's the calculation. The flat 20 per cent amounts to $800. Subtract this $800 from $4000 and you have $3200 which is multiplied by 1/8 since there is an estimated life of 8 years. Then multiply by 1/2 because the equipment was bought on July 1. This multiplication yields $200.

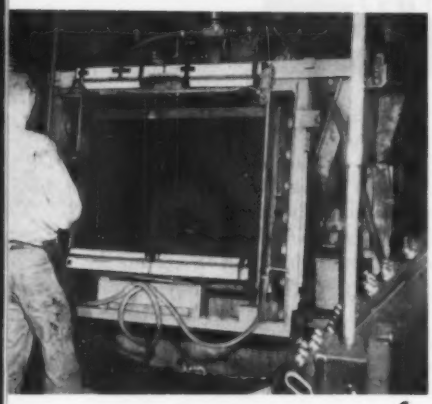
Straight Line Method
$4000 x 20% ... $800
$3200 x 1/8 x 1/2 ... 200
Total $1,000
Declining Balance Method
$4000 x 20% $800
$3200 x 1/8 x 1/2 x 2 400
Total $1200

If the declining-balance method is used and the equipment was new, the firm would be entitled to $1200 as its first year's depreciation deduction. And the calculation looks like this. Again you get $800 for the flat 20 per cent deduction. Subtracting this from $4000 gives $3200. Now multiply by 1/8 and then by 2 since this is the 200 per cent declining-balance method. And your total is now $1200.

Stop. I'm convinced. This dilemma of depreciation can't be beat. And if you can't lick em, join em. Starting tomorrow this foundry and every thing in it goes on a realistic depreciation schedule. I've been fooling myself long enough. ■ ■ ■

GREEN SAND MOLDING STRIKES BACK

by Jack H. Schaum / Editor



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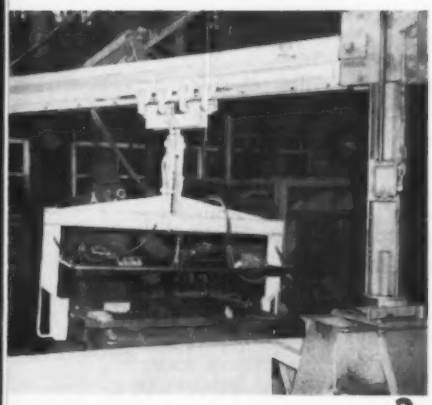
Green sand molding is proving its competitive ability by fighting its way back into the number one production position at Central Foundry Div., GMC, Danville, Ill. Green sand molding has taken quite a pummeling throughout the industry from such new techniques as shell molding, CO_2 process, plaster molding and ceramic molding, not to mention permold, die casting and even forging. But spurred by competition it's making a fast comeback.

Only two years ago shell molding was in the driver's seat for production of the Pontiac crankshaft. Today, improved green sand molding technology has won back the job of shaping close to a half million 1959 Pontiac crankshafts. Three recent advances account for this success—1) better automatic molding machines, 2) special molding sands, and 3) a nuclear moisture gage for sand control.

1 . . . Two high-speed automatic jolt-squeeze-strip machines turn out 100 complete molds per hour. Completed mold contains 1200 lb of sand, has an 85-90 mold surface hardness and forms two crankshafts. Cope half is visually inspected in Fig. 1. In Fig. 2 a special motor driven fixture keeps cope parallel to drag during mold closing so as to prevent crushes and misalignment.

2 . . . Green sand molding lends itself to design flexibility permitting narrow spacing and wide flare of counterweights. Ability to make deep draws can be attributed to new molding sand mix and the mull-aerate-mull sequence before use. Sand is aerated between its two mullings and again on the delivery belt to keep it fluffy for optimum moldability.

3 . . . GM foundrymen are leading the way in demonstrating the importance of moisture control for



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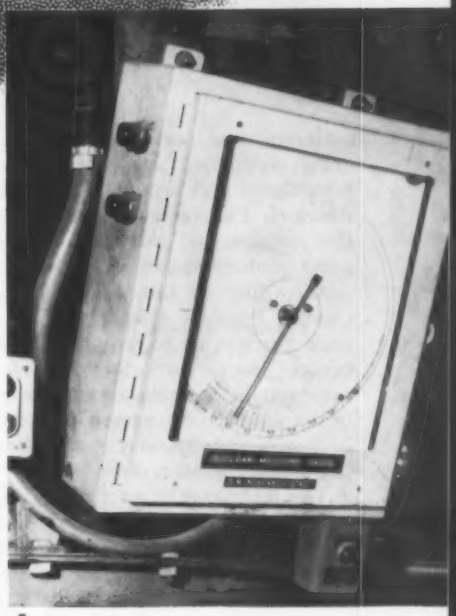

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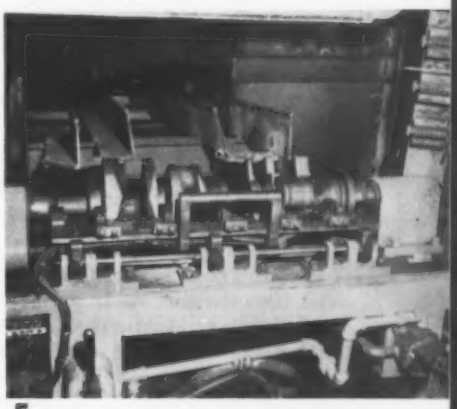

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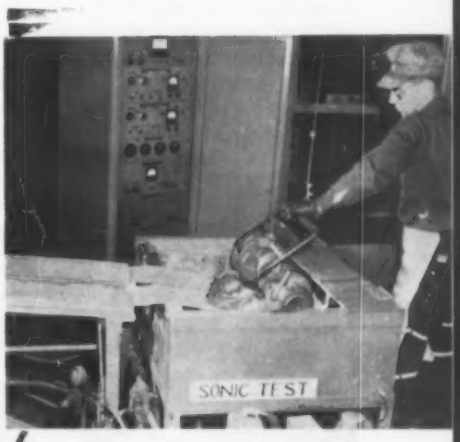

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optimum sand performance. With no moisture-measuring equipment available to meet their needs for high speed and accuracy, Central Foundry and GM Research Laboratory engineers collaborated to solve the problem by designing a nuclear moisture gage using plutonium-239.

According to James H. Smith, general manager, Central Foundry Division, "This new sand moisture gage permits us to maintain a more exact moisture content than ever before and is expected to correct substantially a variety of foundry problems." Accuracy of the sand moisture gage is better than plus or minus 0.05 per cent by weight over a range of 2.5 to 5.0 per cent moisture content.

The technique, conceived by M. J. Diamond, Central Foundry Division research engineer, utilizes fast neutrons emitted from 32 grams of plutonium-239 mixed with beryllium powder and sealed in a stainless steel capsule. Fast neutrons collide with hydrogen nuclei in water atoms producing slow neutrons that can be counted electronically. Number of slow neutrons is directly proportional to sand's moisture content. Slow neutrons are counted in 45 seconds with an electronic device that also calculates exact amount of water to add to the sand mix (Fig. 3). Figure 4 is a close-up view of the nuclear moisture gage.

Before the crankshafts can leave the plant they must pass through a quality proving ground that rivals a missile acceptance test.

First comes magnetic particle inspection and ultraviolet light to prove absence of surface imperfections (Fig. 5). Then the crankshafts are lowered into a sonic test chamber and automatically struck with a metal hammer. Internal discontinuities will lower the frequency and send out the reject signal (Fig. 6).

Next the castings are immersed in water and probed internally by ultrasonic beams for possible hidden flaws (Fig. 7). And finally a representative sampling is subjected to cobalt-60 radiation, the atomic camera that can see inside a casting and spot hidden trouble (Fig. 8).

Only castings passing all these inspections are permitted to be shipped—to the final inspectors . . . the General Motors customers. ■ ■ ■

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1959 CASTINGS CONGRESS PAPERS

■ The technical articles appearing in this preview section of MODERN CASTINGS are the official 1959 AFS Castings Congress papers—the most authoritative technical information available to the metalcasting industry.

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SOLIDIFICATION TIMES OF SIMPLE SHAPED CASTINGS IN SAND MOLDS

By J. Berry, V. Kondic and G. Martin

ABSTRACT

A critical review of experimental and theoretical work concerned with the time of solidification of simple sand-cast shapes reveals the existance of many controversial points. These arise through the several assumptions made in the basic mathematical treatments of the rate of solidification when applied to sand cast shapes.

The assumptions generally made in these equations have been re-examined in this work, and certain experiments carried out to check them.

The solidification times of three simple shapes made in three casting alloys (Al with 12 per cent Si, Cu with 8.5 per cent Al and eutectic carbon equivalent cast iron) have been measured experimentally for a large range of dimensions and for several mold conditions. A prediction of the solidification times for the particular range of sizes and shapes examined, has been shown to be generally possible, providing that the values of physical constants for the mold and casting media, mean values of mold-metal interface temperature, and the maximum temperature attained in the mold after pouring are available.

The chilling power of several mold materials under various conditions of the mold have been determined by a calorimetric method. In addition, the prediction of chilling power has been attempted by means of a theoretical method. A satisfactory agreement between the two methods has been found, and reasons for the deviation occurring have been put forward.

PART I
LITERATURE REVIEW AND PRELIMINARY WORK

INTRODUCTION

Soundness is the aim one strives for in most sand castings. The methods practiced to achieve this objective vary, but are based mainly on the choice of appropriate alloy and casting technique and, when possible, on consideration of the casting design. For a given casting design the soundness is controlled chiefly by risering and running methods of castings, by metallurgical controls of the alloy and the mold, and, in addition but less frequently, by the application of chills and paddings. In the greatest number of cases the approach to solving the problem of casting soundness in industry is essentially empirical, and only recently, and with a moderate degree of success, has a more scientific method of dealing with this problem been attempted.

The reasons for this belated application of science are readily apparent, since the solution to the problem of casting soundness depends mainly on the application of basic scientific knowledge from three different fields; flow of metal into the molds (hydraulics), heat flow from the casting into the mold (heat transfer) and laws of solidification of alloys (physical metallurgy). However, a good deal of such basic knowledge is still lacking in these fields, although a steady progress has been maintained during recent years. This paper is an attempt to review the present position in one of these fields, namely, that of heat transfer.

In the field of heat transfer two major difficulties have been encountered. First, the solution of heat flow equations requires the availability of thermal data on both the metal and the mold, data which are not yet generally available. Second, shaped castings in sand molds present such variations of designs that a purely mathematical approach to solving the heat transfer problems in such cases is almost impossible. Consequently, the important question that immediately arises is whether a theoretical approach to the heat flow problem in sand molds is worth while. The question of collection of thermal data is not unsurmountable, but the question of applying such data still remains to be discussed.

Empirical Relationship

The most significant early work with the question of heat flow in sand molds is due to Chvorinov.[1] Fundamentally, he showed that the theoretical problem of heat transfer in molds can be reduced to an empirical relation; that is, solidification time in a mold is dependent on the ratio of volume to surface area of the casting. More recently, some American workers have shown that Chvorinov's relationship is

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subject to certain limitations, particularly those concerning the size and shape of castings. This has also been confirmed by other workers.

The main outcome of such theoretical studies could be summarized as follows: Heat flow equations for certain types of simple-shaped castings can be reduced to a few elementary relationships which can be then used to predict solidification time of geometrically similar shapes. There is little doubt that further theoretical progress in this field is most likely to continue in the same general direction—toward obtaining basic heat flow relations which are derived from the heat flow theory combined with the experimental data. These relationships could be more readily applied than could the more complex mathematical equations of heat flow.

It is a distant but, nevertheless, a foreseeable hope that such relationships will be found to embrace the basic sizes and shapes which are encountered in the sand foundry industry.

Assuming that the knowledge concerning the solidification times and rates in a sand mold exist, the question of practical application of such data requires some examination. Perhaps the most direct use of solidification-time data is for dimensioning risers in shaped castings. If a riser is to efficiently feed the solidification shrinkage of a casting, it is essential to ensure that the casting solidifies towards the riser. At the same time, from an economic and production standpoint, it is required that the riser should be of a minimum size.

A quantitative solution of such problems require data concerning the times of solidification in sand molds. The problem of successful risering of castings, of feeding distances, i.e., of alloy characteristics, is thus a heat flow as well as a metallurgical problem.

Other possible uses of heat flow in sand founding are—the control of casting stresses, the calculation of knockout times and the interpretation of cast structure with their resultant mechanical properties.

The object of the present paper is that of reviewing some recent results in heat flow studies in sand molds. A later paper will examine the application of such data to the production of sound sand castings. Some recent work of the authors is used for the basic construction of the present paper.

LITERATURE REVIEW

The general problem of heat transfer in relation to shaped castings in sand molds can be considered under three headings:

A) Basic laws of heat transfer.
B) Variables of shape and size.
C) Variables of the mold and casting material.

Basic Heat Transfer Laws

Castings (ingots as well as shaped castings) fall into the group of unsteady state heat transfer phenomena. The development of the general heat flow equation for sand castings, and the conditions of its application, have been reviewed by Ruddle[2] and King.[3] For that reason only a brief statement of this aspect will be made here.

The mathematical statement of the problem can be made with respect to the case of a plane body of semi-infinite length and width initially at temperature θ_1, brought suddenly into contact with a second, similarly shaped body, initially at a lower temperature θ_2. This second body (e.g., the mold) absorbs per unit area a certain amount of heat q from the first body (e.g. molten metal) in time t. In order to set up a mathematical equation which will give the amount of heat exchanged between the two bodies with respect to the time, specific conditions must be stated. Still further conditions are necessary for this equation to be solved.

Conditions Necessary

Both of these aspects of the problems have been adequately reviewed by Ruddle and King. The important conclusion which is obtained from such an analysis is that an equation for the above case, relating to the exchanged heat q per unit area with respect to the metal and mold temperatures θ_1 and θ_2, respectively, can be obtained when the following conditions are fulfilled:

1) The interface is at constant temperature θ_1' during the period for which the heat flow is studied.
2) The mold has an infinite heat capacity, i.e., will not loose any heat to the surroundings during the same period.
3) The thermal properties (specific heat, c, and thermal conductivity, k) for both metal and mold are constant and not variable for the temperature range under examination.

Under these conditions the heat absorbed per unit area by the mold is given by:

$$q = \frac{2}{\sqrt{\pi}} \cdot (\theta_1 - \theta_2) \cdot b_2 \sqrt{t} \qquad (1)$$

where $\theta_1' > \theta_2$ and $\theta_1 > \theta_1'$ and constant b_2 is the property known as the heat diffusivity of the mold: $b_2 = \sqrt{k_2 \rho_2 c_2}$, where all the quantities have been defined above and ρ_2 is the density of the mold.

From the point of view of applying this heat flow equation to the shaped castings in sand molds the following problems arise:

1) Errors due to the finite size and variable shape of castings as distinct from the plane and infinite bodies.
2) Errors due to the lack of constancy as well as the experimental shortage of exact data on the value of the interface temperature.
3) Errors due to the changes in the thermal properties of the mold and metal as function of temperature.

Geometrical Limitations Errors

There is no way of predicting or assessing quantitatively the error due to the geometrical factors of shaped casting apart from the actual experimental measurement. Indeed, the whole field of application of heat transfer laws to shaped sand castings depends at present on obtaining sufficient experimental evidence to understand full implications of any specific heat transfer equation. Once the stage is reached

when the limitations of simplified equations are fully understood on the basis of experimental evidence, then the comparatively simple task which will remain is that of feeding the thermal data into the appropriate equations to obtain full benefit of such data in metal founding.

Interface Temperature Errors

The question of the interface temperature raises certain separate issues:

A) Nature of the contact between the metal and molding sand.
B) Measurement and calculation of the interface temperature.
C) Temperature distribution at the interface.
D) Heat capacity of the mold.

Nature of Contact. Recent research[4] on metal penetration into sand compacts has indicated its dependence on grain size, superheat of the metal cast, the time of contact and metallostatic pressure. This study was carried out using an inert atmosphere or hydrogen, under which conditions metals do not wet silica sand. Nevertheless, the penetration measured was so considerable that under normal sand casting conditions the effect of the type of contact on the variables in the heat transfer equation cannot be neglected.

Gittus,[5] in studying the quality of gray and white-cast iron surfaces for various sand conditions, has suggested that under normal foundry conditions wetting will occur with carbon-free sands due to the preferential formation of silica-wetting iron oxide. Nonwetting occurs where pitch or coal dust is present in the sand due to preferential formation of the gaseous carbon oxides with these materials. Penetration of brass and aluminum has been studied statistically[6] under normal foundry conditions. Penetration of brass cast at 1295 C (2363 F) was found to be considerable and to depend upon liquid pressure, sand grain size, density and moisture.

However, no penetration was observed with an aluminum-5 per cent silicon alloy cast at 705 C (1301 F). This absence of penetration was explained as resulting from the low running quality of the material at these temperatures. Reference was made to similar work[7] on commercially pure aluminum. It seems doubtful that this applies to all light alloys when poured with their usual superheats.

In addition to the sand grains immediately in contact with the cast metal, attention must be directed to the adjacent sand grain layers. The expansion of sand compacts has been studied by Atterton,[8] and appears to hold values between 1.6-1.8 per cent (linear per cent) for temperature between 600 (1112) and 1000 C (1832 F). This expansion is attributed to the ballooning of the interstitial air spaces. Measuring sand movements in actual molds by spherical ended silica probes, Gittus[9] has shown how such an expansion of interstitial air spaces proceeds in the presence of solidifying cast iron.

The direction of the expansion varies with time after pouring, and also with the sand conditions, that is, whether the sand is green or dry. Dry sand first expands into the skin of solidified metal, since the rigidity of its cooler layers is greater than that of the thin solidified metal skin. As the casting solidifies further, and the precipitation of the eutectic begins, the metal expands out into the sand. In green molds the cooler portion of the sand at first has a lower rigidity, consequently an outward movement of the hot sand takes place.

This continues until the rigidity of the drying sand is sufficient to change the direction. Hereafter the sand moves in on to the casting until the expansion from the eutectic precipitation takes place.

To summarize, the available evidence confirms the assumption of good thermal contact between metal and mold with the probable exception of two cases:

1) When casting alloys of pronounced oxide film character (e.g., aluminum alloys especially when cast at low temperatures).
2) When casting in green sand molds during the period of drying out of the layers of sand adjacent to the interface.

With castings made from high-melting-point temperature alloys the second factor is small, and consequently there remains only the former factor to be considered. Paschkis,[10] using the electrical analog method of calculation of heat transfer, has computed the effect of a probable air gap in the solidification time of aluminum castings. He shows that with an air gap formation the solidification time is altered by about 44 per cent.

Unfortunately, no details of time of formation or thickness of air gap are given, so that this result must be regarded only as an indication of the order of magnitude of the effect. This effect is probably far more pronounced at low temperatures when heat transfer by radiation from a metal surface is not of the same order as the heat transfer through sand by conduction.

Calculation of the Interface Temperature. One available relationship for calculating the interface temperature is from Riemann.[11] This equation for the temperature θ_i, attained at the interface of plane semi-infinite bodies initially at temperatures θ_1, and θ_2, is

$$\theta_i = \frac{b_1 \theta_1 + b_2 \theta_2}{b_1 + b_2} \qquad (2)$$

where b_1 and b_2 are the respective mean heat diffusivities. Halbart[12] approximates this to

$$\theta_i = \frac{b_1 \theta_1}{b_1 + b_2}$$

In addition, Halbart gives the following relationships for copper and cast iron:

$$\theta_i = 0.942\, \theta_1 \text{ for copper.}$$

$$\theta_i = 0.868\, \theta_1 \text{ for cast iron.}$$

Neither Riemann's nor Halbart's relationships take account of the fact that during casting the mold is part of the time in contact with liquid and part with solid metal, and will thus give only an approximate result for the interface temperature. The existence of

pre-solidification and solidification periods of heat transfer could be taken into consideration in the following way.

An average value $\bar{\theta}_1$ might be used instead of θ_1 by considering solidification in two parts:

A) Mold in contact with a liquid mass at temperature

$$\theta_1' \text{ for } t_1' \text{ sec.}$$

B) Mold in contact with a solid mass of average temperature

$$\theta_1'' \text{ for } t_1'' \text{ sec.}$$

The times of contact would hold the ratio:

$$\frac{t_1'}{t_1' + t_1''} = \frac{q_1^2}{q_t^2}$$

where q_1 is sensible heat of casting.
q_t is total heat of casting.
i.e.,

$$\frac{t_1'}{t_1' + t_1''} = \frac{(c\Delta\theta)^2}{L^2 + 2Lc\Delta\theta + c^2\Delta\theta^2} \qquad (3)$$

Thus, from the ratio t_1'/t_1'' a weighted mean value $\bar{\theta}_1'$ to replace the quantity θ_1', in equation (2), is obtained.

In addition, we write b_1 as

$$b_1' = \sqrt{k_1 \rho_1 \left(c_1 + \frac{L_1}{\theta_m}\right)}$$

$\bar{\theta}_1'$ is then calculated as

$$\bar{\theta}_1' = \frac{\bar{\theta}_1 b_1' + \theta_2 b_2}{b_1' + b_2} \qquad (2b)$$

The values of $\bar{\theta}_1'$ have been obtained experimentally by Ruddle and certain other workers,[15] and will be discussed more fully in subsequent paragraphs.

Temperature Distribution at the Interface. In the two preceding sections the nature of the interface and the possibility of calculating the interface temperature have been considered.

These features are intimately connected with the temperature distribution at the mold-metal interface. The type of temperature distribution assumed greatly affects the accuracy of calculation of solidification time. This particular problem has been examined by Girshovich and Nekhendzi,[16] who consider the following cases:

1) Exact gaussian distribution across the interface.
2) Straight line distribution in the solidifying casting, taking account of the thermal capacity of the solid metal.
3) As (2) above, but ignoring thermal capacity.
4) Ignoring temperature gradient in solidifying casting.

The errors involved in the mold constant used in the calculation of rate of solidification vary according to the distribution assumed. For steel in green sand molds the most serious variation 7 per cent is in (4). Smaller errors of 2 or 6 per cent are achieved with (3) when calculated from the distributions obtained in the metal or the mold, respectively. Identical results come from (2) and (1) (the correct distribution).

The errors incurred with steel cast in metal molds are more serious. Case (4) (from mold only) 200 per cent; case (3) 27 and 39 per cent; case (2) 11 and 9 per cent, as calculated from the distributions in the metal and mold, respectively. It is worth noting that changes of 10, 30 and 200 per cent in the mold constant would lead to changes of 18, 41 and 89 per cent in solidification time, all other things being equal. For present purposes, i.e., sand molds, the above errors are of a smaller order than many of those arising from the use of thermal constants of doubtful accuracy, as well as from other assumptions.

Heat Capacity of Mold and Air-Mold Interface. In addition to the mold-metal interface, the external or air-mold interface must be considered.

Chvorinov,[1] Ruddle[14] and many others have shown that during the solidification of sand castings of thickness not greater than that of the surrounding molding sand, the external mold face temperature does not rise significantly over that of the surroundings.

The antithesis of this condition is provided by shell molds, the outer surface temperature of which was found to increase appreciably during the solidification period, according to Pellini and co-workers.[17]

Metal and Mold Thermal Properties Errors

Bearing in mind the scarcity of data in this field, one must carefully consider the important assumption of a constant value for the following:

A) Thermal conductivity to the mold k_2.
B) Density of the mold ρ_2.
C) Specific heat of the mold c_2.
D) Specific and latent heats of the liquid metal c_1 and L_1.

It is a well-understood principle that conductivity and specific heat of continuous solids vary considerably with temperature. Consequently, in heat-flow problems a mean value is taken appropriate to the type of dependence. For most purposes a simple integrated mean is quite satisfactory. Russell[18] and Eucken[19] have pointed out the complexity of the nature of heat flow through porous media, so that the foregoing treatment must be performed graphically on the best set of data available, unless a measured mean value of k_2 has been obtained for the temperature concerned.

Similar remarks regarding complexity apply to the dependence of both c_2 and ρ_2 on temperature, although in the latter case it is generally considered permissible to insert the room-temperature value of ρ_2 in calculating b_2.

Shape and Size Variables

In general, shaped castings produced in sand molds and similar materials are of extremely varying design. External and internal surfaces may be of such a complicated form that it is impossible to reduce

such a casting into a number of simple geometric shapes. Similarly, the weight of the casting may vary from a few ounces to several tons. In general, it would be desirable to predict the solidification times of such complicated castings, because such castings are most difficult to produce and lead to high losses if defective. With a clear picture of the solidification rate and mechanism, one would expect that a more rational approach to the casting problem would reduce the number of defective castings.

An approach to this problem must necessarily proceed along the line of studying the solidification times and rates of simple geometric shapes. In reviewing the available data on the heat transfer in simple shaped castings in sand molds, the general equations of heat transfer in plates, cylinders and spheres will be summarized.

Plates. For a wide plate casting, the area of whose main faces is A, and the area of whose end or minor faces may be neglected, the end point of solidification t_s is obtained from

$$q = A \cdot \frac{2}{\sqrt{\pi}} (\theta_i - \theta_o) b_2 \sqrt{t_s} \qquad (1a)$$

equating this with the heat lost during solidification we have

$$\rho_1 V [L_1 + c_1(\theta_i - \theta_m)] = A \cdot \frac{2}{\sqrt{\pi}} (\theta_i - \theta_o) b_2 \sqrt{t_s}$$

$$\frac{V}{A} = \left(\frac{2(\theta_i - \theta_o) b_2}{\sqrt{\pi} \rho_1 [L_1 + c_1(\theta_i - \theta_m)]} \right) \sqrt{t_s}$$

$$\frac{V}{A} = k \sqrt{t_s} \qquad (4)$$

where V is the volume and θ_i is the casting temperature (assuming that there is no drop in temperature during pouring)

θ_o is the initial temperature of the mold.
θ_m is the solidification temperature.
L_1 is the latent heat of solidification.

The validity of this equation further depends upon the assumption that the sensible heat $\rho_1 V c_1 (\theta_1 - \theta_m)$ is liberated with θ_i constant, so that this former quantity may thus be added to the latent heat. The quotient V/A is generally written R and therefore we obtain

$$t_s = q \cdot R^2 \qquad (5)$$

Alternatively one can apply equation (1) to determining the depth d_t to which the casting has solidified at a time t.

$$q_t = A \frac{2}{\sqrt{\pi}} (\theta_i - \theta_o) b_2 \sqrt{t}$$

$$(d_t A) \rho_1 [L_1 + c_1(\theta_i - \theta_m)] = \frac{2A}{\sqrt{\pi}} (\theta_i - \theta_o) b_2 \sqrt{t}$$

$$d_t = \left(\frac{2(\theta_i - \theta_o) b_2}{\rho_1 [L_1 + c_1(\theta_i - \theta_m)]} \right) \sqrt{t} \qquad (4b)$$

$$d_t = k' \sqrt{t} \qquad (4c)$$

where k' is termed the mold constant.

It was Chvorinov[1] who first suggested that equation (5) holds good for many castings, if external curvature and end effects are neglected. In order to substantiate this, he showed a double logarithmic plot of

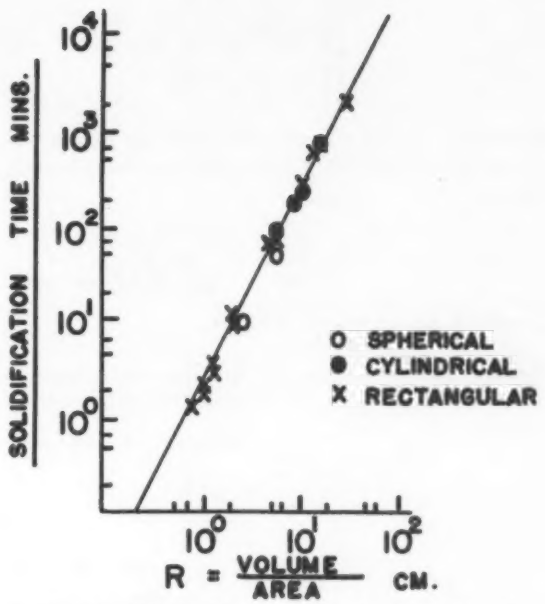

Fig. 1-1 — Relationship of volume/surface ratio to solidification time.[1]

R and t_s (Fig. 1-1) which revealed a good agreement for steel castings of various sizes and shapes. The results included certain data of Briggs and Gezelius.[20]

The value of q was derived in two ways, both apparently in good agreement. The first method employed was that previously indicated in equation (1a), that is, from the thermal constants involved. The second involves the calculation of q as defined by Schwarz's solution:[21]

$$L \rho_1 \sqrt{\frac{\pi}{4}} q = \frac{b_2 e^{-q^2/4a_s} \theta_m}{\frac{b_s}{b_2} + G(q/\sqrt{4a_s})} - \frac{b_2 e^{-q^2/4a_1} \Delta\theta}{1 - G(q/\sqrt{4a_1})} \qquad (6)$$

where θ_m is the temperature of solidification.
$\Delta\theta$ is superheat, i.e. $\Delta\theta = \theta_i - \theta_m$
and subscript
1 Indicates liquid metal.
s Solid metal.
2 Mold.

Unfortunately, the assumptions of neglecting curvature and corner effects have not always been recognized by subsequent investigators. In examining the general application of equation (5), Ruddle and Skinner[22] have shown that a correction can be made for corner effects. The correction consists of adding to the surface area unaffected by the corners the equivalent plane surface area of the corners. This equivalent area is obtained as the product of a semi-empirically derived factor and the actual surface area of the corners.

Spheres and Cylinders. Regarding shapes other than flat plates, few workers have attempted to derive the fundamental equations describing either progress of solidification or total solidification time.

Halbart[12] has examined the case of the sphere, in which the basic differential equation for unsteady heat flow was translated into the form:

$$\frac{\partial \theta}{\partial t} = a_2\left(\frac{\partial^2 \theta}{\partial x^2}\right) \qquad (7)$$

$$\frac{\partial x}{\partial t} = a_2\left(\frac{\partial^2 x}{\partial r^2}\right) \qquad (7a)$$

where $X = \theta r$ and r is the radius of the sphere. He arrives at the following expression for solidification time:

$$t_s = \frac{9}{\pi a_2^2}\left[\sqrt{1+\frac{\pi \rho_1 [L_1 + c_1(\theta_i - \theta_m)] - 1}{3\rho_2 c_2 \theta_i}}\right]\left(\frac{V}{A}\right)^2 \qquad (8)$$

$$t_s = q' \cdot (R_s)^2 \qquad (8a)$$

Halbart then compares the quantity of q^1 in the above equation with q in equation (5) in the following way

$$\sqrt{t_s} = A' \cdot \frac{V}{A}, \text{ for sphere.}$$

$$\sqrt{t_s} = B' \cdot \frac{V}{A}, \text{ for plate.}$$

where $A' = \sqrt{q^1}$ and $B' = \sqrt{q}$
and that shows B′ and A′ are connected in the following way:

$$B' = A' + \frac{\sqrt{\pi}}{\sigma}\alpha_2 A'^2$$

which, for sand molds quoted with $\alpha_2 = 0.07$, becomes: $B' = A' + 0.02\,A'^2$

B′ and *A′* are given for the cases of copper and cast iron in sand molds:

Metal	B′	A′
Copper	6.8	6.1
Cast iron	5.9	5.3

Thus it can be readily shown that, since $(A')^2$ cannot be negative, a plate will solidify in a longer time than a sphere of equal volume-to-surface ratio. Trenckle[23] has used forms of the equations to calculate the permissible pouring times of various shapes. The other shapes he considered were examined using theoretical work on temperature distribution.[25-27]

Mold Temperature Distribution

Abcouver[24] takes a rather different approach to calculation of solidification time of any given shape. He presents a single equation describing the temperature distribution in the mold, and the casting which takes into account the temperature discontinuity at the mold-metal interface. Exactly how the equation has been derived is not specified. However, it is used to determine total solidification time t_s through knowledge of volume-to-surface ratio and the usual thermal constants:

$$\frac{b_2}{\pi(b_1+b_2)}\sqrt{4\pi a_2 t_s\left(\frac{A}{V}\right)^2} = \frac{L_1}{c_1\theta_1} + \frac{H}{H+1} \qquad (9)$$

where $H = \dfrac{\theta_1 - \theta_m}{\theta_m}$ and $\dfrac{L}{C_1\theta_1} + \dfrac{H}{H+1} = 0.35$ for cast iron.

Apparently, this equation may be applied to any simple-shaped casting. Chvorinov,[28] in his most recent paper, accounts for the effect of casting variables L_1 and θ_1 on the value of κ' in the equation:

$$d_f = k'\sqrt{t} \qquad (4c)$$

If the equation is divided by *R*, (the ratio V/A) he suggests that for conditions of superheat (U)

$$U = \theta_i - \theta_m$$

$$\frac{d_f}{R} = \frac{k'_o}{R}\sqrt{t} - \frac{Uc_1}{RL_1} \qquad (10)$$

may be written for the plate, where κ'_o is the value of κ' at $\theta_1 = \theta_m$. This gives a straight-line relationship of $\dfrac{d_t}{R}$ to $\dfrac{\kappa'_o}{R}\sqrt{t}$ for this particular body. Chvorinov extends this to cylindrical and spherical castings by assuming that heat transferred over a given area is identical in all three basic shapes.

Experimental Evidence

It is simple to show by geometry then that for spheres,

$$d_s = d_p\left(1 - \frac{d_p}{r}\right) \qquad (11)$$

for cylinders,

$$d_c = d_p\left(1 - \frac{d_p}{2r}\right) \qquad (12)$$

where d_p is d_t as derived for plates by equation (10). Thus, he shows that three families of curves can be drawn—one linear, and two parabolic—each curve a family of different superheats. Experimental evidence is given to confirm these relationships for steel castings, and shows fairly good agreement. The relationship of $\dfrac{d}{R}$ to $\dfrac{t}{R^2}\kappa'^2_o$ is also provided, and appears to be a better means of expressing the result. Figure 1-2 shows a set of curves relating $\dfrac{d}{R}$ to $\dfrac{t}{R^2}$, a particular case of this latter relationship.

The present authors feel that it would be worthwhile to examine the basic expressions for spheres and cylinders in the hope that these expressions might possibly be approximated to the simple form of equation (5).

Jaeger[29] gives the following relations for $\dot{q}$, the rate of heat extraction for unit area for long cylinder and spheres with radius *a* as:

For long cylinders:

$$\dot{q} = k_2(\theta_i - \theta_0)\frac{4}{a\pi^2} I\left(0, 1, \frac{a_2 t}{a^2}\right) \qquad (13)$$

For spheres:

$$\dot{q} = k_2(\theta_i - \theta_0)\left[\frac{1}{\sqrt{\pi a_2 t}} + \frac{1}{a}\right] \qquad (14)$$

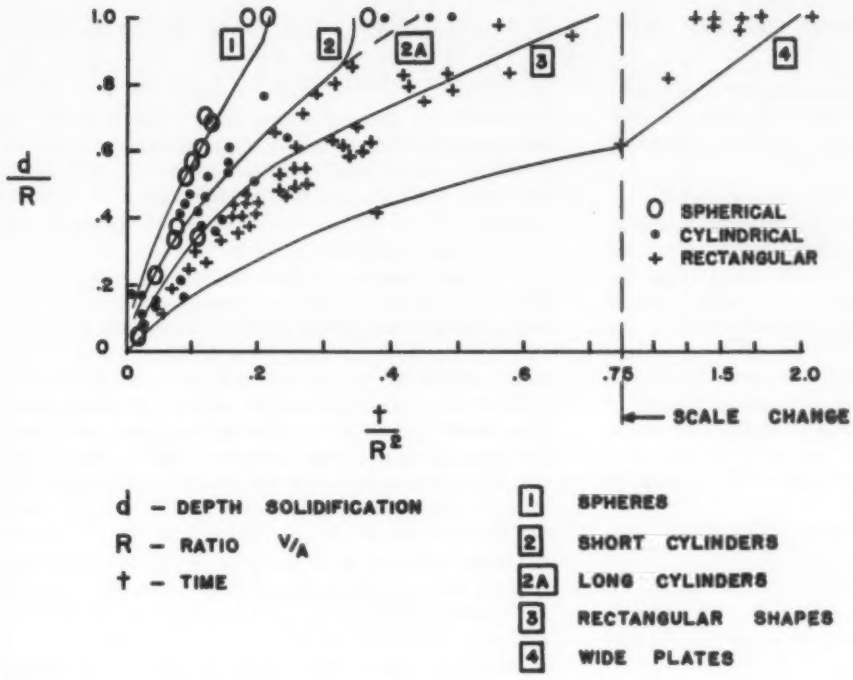

Fig. 1-2 — Theoretical and measured values for the relationship d/R and d/R².

However, for small values of $\frac{\alpha_2 t}{a^2}$ equation (13) becomes

$$\dot{q} = k_2(\theta_i - \theta_0)\left[\frac{1}{\sqrt{\pi \alpha_2 t}} + \frac{1}{2a}\right] \qquad (15)$$

Since values $\frac{\alpha_2 t}{a^2}$ are small for most sand castings poured with normal amounts of superheat, the use of equation (15) may be permitted. Equations (15) and (14) are written in a general form:

$$\dot{q} = k_2(\theta_i - \theta_0)\left[\frac{1}{\sqrt{\pi \alpha_2 t}} + \frac{1}{RC_1C_2}\right] \qquad (16)$$

Since

R = a/3 for sphere.
R = a/2 for long cylinder.

Where

$C_1 = 3$ for sphere.
$C_1 = 2$ for cylinder.
$C_2 = 1$ for sphere.
$C_2 = 2$ for cylinder.

If we now consider q the heat flowing across an area A in time t, we have an integrating equation (16)

$$q = \sigma b_2 \sqrt{t} A(\theta_i - \theta_0) + \frac{k_2 t(\theta_i - \theta_0)}{C_1 C_2 R}$$

(where $\sigma = 1.13$)

again as before:

$$q = V \cdot \rho_i \left[L_i + c_i(\theta_i - \theta_m)\right]$$

or writing $q = V \cdot \rho_1 \cdot \bar{q}_1$

we have:

for t_s $\quad \sigma b_2 A\sqrt{t_s}(\theta_i - \theta_0) + \frac{k_2 t_s A(\theta_i - \theta_0)}{RC_1C_2} = V \cdot \rho_i \cdot \bar{q}_1$

or $\quad \sigma b A\sqrt{t_s} V + \frac{k_2 t_s A}{RC_1C_2} \cdot V = V \cdot \rho_i \cdot \bar{q}_1$

Dividing throughout by V and writing $\frac{V}{A} = R$ we have:

$$\sigma b_2 \sqrt{t_s}\frac{V}{R} + \frac{k_2 t_s V}{R^2 C_1 C_2} = \rho_i \bar{p}_i$$

It is eventually found that for cylinders and spheres:

$$t_s = \frac{R^2}{\left[\frac{\sigma b_2 V}{2\rho_i \cdot \bar{q}_1} + \sqrt{\frac{V}{\rho_i \bar{q}_1}\left(\frac{\sigma^2 b_2^2 V}{4\rho_i \bar{q}_1} + \frac{k_2}{C_1 C_2}\right)}\right]^2} \qquad (18)$$

Equation (5) may be written in a similar manner for plates:

$$t_s = \left(\frac{\rho_i \bar{q}_1}{\sigma b_2 V}\right)^2 R^2 \qquad (19a)$$

Thermal Properties of Casting and Molding Media

An attempt to predict solidification time of a casting, whether by calculation or by electrical analog methods, depends for its accuracy on the knowledge available on the values of the thermal properties of the casting and molding media. The basic properties required are:

A) Thermal conductivities of mold, liquid and solid metal, k_1, k_s and k_2.
B) Specific heats of mold, liquid and solid metal, c_1, c_s, c_2.

C) Latent heat of fusion of liquid metal L_1.
D) Densities of the mold, liquid and solid metals ρ_1, ρ_m, ρ_2.

The appendix of Ruddle's monograph[2] deals adequately with such data available at the time of publishing (1950),* hence, it is proposed only to examine similar data published since that time.

In the field of metals few new contributions have since been made. This is indeed unfortunate and may account for discrepancies obtained between predicted and experimentally obtained solidification time values. The determination of specific and latent heats of metals and alloys necessitates expensive and often complicated apparatus, particularly when high-melting-point materials are to be examined. Successful methods have been developed for measurement of specific heats by the cooling curve method for solid metals. However, this method has only of late been applied to liquid metals, and much work remains to be done.

Latent heat value measurements have been even more neglected. In some cases, thermodynamic methods can be utilized to obtain latent heat values. Ruddle and Mincher[30] have given values for several materials which have been calculated from the density of the solid at the melting point.

Thermal Constants

Abcouver[24] and Halbart[12] have given some values of thermal constants of metals which appear to have been determined experimentally, but no data have been given concerning the accuracy of the figures. Until this dearth of information on thermal data of metals has been dealt with, the progress of many heat flow calculations in many metallurgical fields will be delayed.

Some strides have been made recently in the field of measurement of thermal properties of molding materials. It is an advantage to classify the methods of determination as follows:

*A 1957 edition of this work is now available.

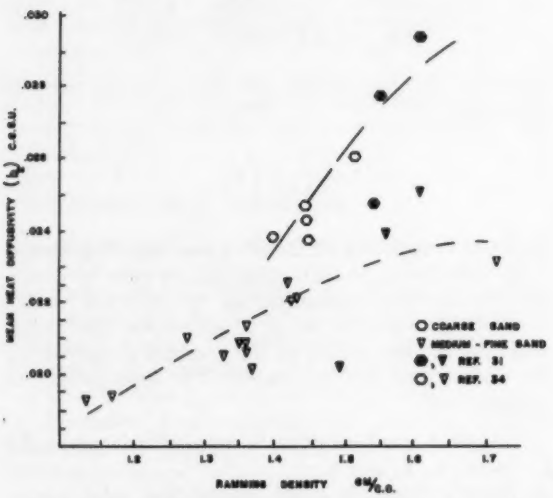

Fig. 1-3 — Variation of mean heat diffusivity b_2 with ramming density.

A) Steady state methods (for k_2, α_2).
B) Unsteady state methods, involving making of castings in molds (for k_2, α_2, b_2, c_2).
C) Methods of calculation (for k_2, α_2, b_2).

Atterton,[31] using a steady state method involving the measurement of radial temperature gradients in small cylindrical sand compacts heated electrically by an axial heating wire, determined values of thermal conductivity k_2 over a wide range of temperature for several mold materials.

The sands examined included coarse and medium fine sands, bonded with various percentages of bentonite, and samples made at three ramming densities. Among the materials examined were also glacial, zircon and olivine sands (all bonded with bentonite) and, in addition, two riser insulating compounds. This work shows the fundamental importance of temperature, grain size and ramming density in affecting the thermal conductivity. However, in applying Atterton's results to solidification problems, care must be taken that a correct mean value is used.

Using unsteady state methods of determination involving melting and casting, many recent experiments have been reported by a number of workers. Ruddle,[14] Ohira,[32] Halbart,[12] Abcouver[24] and Briggs and Locke,[33] as well as the present authors.[34] Ruddle[14] used the method of Chvorinov for determining α_2 the mean temperature diffusivity for the following materials:

1) Fine silica sand, (Erith), in dry state.
2) Naturally-bonded sand (Mansfield), in dry state.
3) Bonded silicon carbide grit.
4) Bonded magnesite.

Interface Temperatures

The determinations were carried out for various interface temperatures, and the results may be readily applied as mean values for relevant cases. Both this method and a mold calorimetric method have been used by the present authors on behalf of a subcommittee of the Institute of British Foundrymen, to determine b_2 for the casting temperature of several alloys. This second method consists of determining b_2, the mean heat diffusivity, by equating heat liberated on solidification of the casting with that absorbed by the mold in the same time.

Determinations of b_2 were carried out on a coarse and a medium-fine sand, so that a comparison can be made with the appropriate figures calculated from Atterton's results for two fairly similar sands from the same geological source (Fig. 1-3). The order of the values of b_2 is in reasonable agreement; however, the difference in slopes is difficult to explain. Halbart,[12] Trencklé[23] and Abcouver[24] also appear to have derived values of thermal conductivity for sands from their experimental work, all of similar order to the other investigators work.[31-34] However, they[12,23,24] give no details of the method used or the accuracy of the results.

Ohira also derived similar values for this quantity for a naturally bonded sand in the green and dry state. He has, in addition, determined the mean specific heat of these sands by calorimetric means. Ohira's

data show good agreement with previous results (Fig. 1-4). Recently Briggs and Locke[33] have published the results of a series of tests to determine the chilling power of a wide range of materials. Unfortunately, no attempt was made to put the results in order of mean thermal conductivity or diffusivity. Results were merely presented as solidification time of a 6-in. diameter sphere poured in a low-carbon steel at a temperature of 1576 C (2867 F) of superheat.

With the use of existing data for mean specific heat of the mold materials and for latent and specific heat of steel, the present authors have derived values of mean themal conductivity and mean thermal and heat diffusivity of the materials used by Briggs and Locke (Table 1-1). The accuracy of these results depends not only on the experimental error but on the data used in the calculation, and so may only be of the order of 10-15 per cent in certain instances. Ohira[32] and work by Kondic and Martin, for the subcommittee of the Institute of British Foundrymen previously mentioned, are the only sources of thermal constants for green sands. Herein lies the advantage of unsteady state methods, as values of the thermal constants for green sands can be given if only approximately.

Green Sand Chilling Power

Although Ruddle and Mincher[14] give the temperature distribution for green sand, no value of b_s or α_s could be obtained using Chvorinov's method. However, the application of a corollary of Schmidt's graphical method[35] might resolve this difficulty. Paschkis,[36] using the electrical analog with Tanasawa's data[37] to study the effect of moisture content in heat extraction, points out that the presence of moisture has little effect after a critical time for a particular interface temperature. Thus, the chilling power b_s, of a green sand would appear dependent on the size of the casting made because of the variable nature of the magnitude of drying out of layers of sand adjacent to the casting.

However, the fact that no value of mean interface temperature has been given to Tanasawa's curves raises the question of the accuracy of Paschkis' results. Although temperature distributions in cores have been

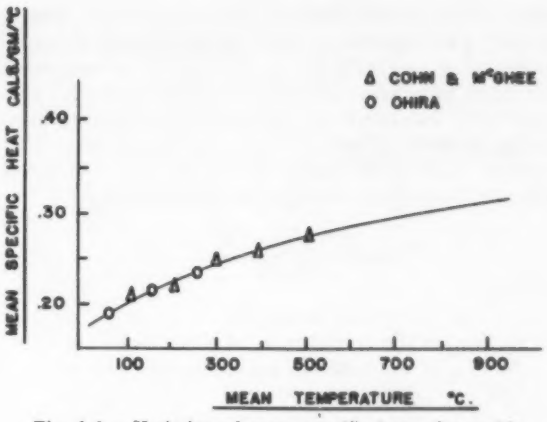

Fig. 1-4 — Variation of mean specific heat of a molding sand with mean temperature of the mold.

measured with good accuracy by Chamberlain and Peters,[38] no one has attempted to determine their thermal properties. Core sand temperature distributions during heating, like those of green sand molds, contain discontinuities which make theoretical analysis difficult.

The method of calculation of thermal properties is due mainly to Russell[18] and Eucken,[19] who have shown that for porous refractory materials such as sand, the observed thermal conductivity of the aggregate k_a depends only upon the apparent conductivity of the pores k_p and the porosity fraction P;

$$k_a = k_p\left(\frac{3}{P} - 2\right) \qquad (20)$$

Russell[18] also gives

$$k_p = k_t + (5.44 \times 10^{-12})\, T^3 X \qquad (21)$$

where

k_p is in cgs units.
k_t is the thermal conductivity of air in cgs units.
T is the absolute temperature in °K.
X is the pore space diameter in cm.

Bell[39] gives an expression for pore space diameter for sands of a two-sieve type distribution and has used

TABLE 1-1 — THERMAL PROPERTIES OF SPECIAL MOLDING MATERIALS*

Materials	Mold Density, gm/cc	Mean Specific Heat, cal/gm/°C	Mean Thermal Conductivity, cgs	Mean Temperature Diffusivity, cgs	Mean Heat Diffusivity, cgs units	Temperature Range C	Temperature Range F
Graphite	2.0	0.35	0.00294	0.00420	0.0454	0-1470	32-2678
Cu-shot	4.4	0.1	0.00338	0.00768	0.0386	0-1470	32-2678
Steel-shot	3.74	0.16	0.00176	0.00294	0.0325	0-1470	32-2678
Silicon carbide grit	3.7	0.24	0.00119	0.00135	0.0325	0-1470	32-2678
Magnesite grit	1.67	0.25	0.00206	0.00494	0.0293	0-1470	32-2678
Alumina grit	1.9	0.30	0.00145	0.00254	0.0288	0-1470	32-2678
Chrome ore	2.14	0.27	0.00130	0.00225	0.0274	0-1470	32-2678
Chamotte	1.48	0.28	0.00144	0.00348	0.0244	0-1470	32-2678
Alumina (bubbled)	0.92	0.30	0.00146	0.00529	0.0201	0-1470	32-2678
Diatomaceous earth 40% coarse sand 60% (mulled)	1.11	0.28	0.00116	0.00373	0.0190	0-1470	32-2678
Diatomaceous earth 40% coarse sand 60% (unmulled)	0.78	0.28	0.00086	0.00394	0.0137	0-1470	32-2678

*Mean thermal conductivity, temperature diffusivity and heat diffusivity derived from results of Briggs and Locke.[33]

this in conjunction with the above equation to obtain a fairly good agreement with the steady state measurements of k_s, as made by Lucks and his co-workers[40] for four unbonded silica sands. More recently, Gittus[41] has extended the method of calculating pore space diameter X to sands of any distribution. This method consists of utilizing the area A_c under the cumulative grading curve in the following way:

$$X = \frac{200\,[\rho_{SiO_2} - \rho_B]}{3A_c \cdot \rho_B} \qquad (22)$$

Where

A_c is the area in gm cm.
ρ_{SiO_2} is the true density of silica in gm/cc.
ρ_B is the bulk density of the aggregate in gm/cc.

Using this method Gittus has obtained relationships of thermal conductivity to the cube of the absolute temperature for the unbonded sands examined by Lucks and his co-workers.[40]

The agreement between these results and those of the experiments is good for all the sands, except the coarse one, where the disagreement varies between 0 and 10 per cent. The same worker has found that the results of Atterton[31] for a bentonite bonded coarse sand (52 A) may be predicted with good accuracy. However, in the case of the fine sand investigated (26 A), considerable disagreement was found. This was thought to be due to the fact that clay bond increases the contact area between the small-sized grains and so invalidates the previous equation.

A PRELIMINARY STUDY OF INTERFACE TEMPERATURE

An examination of the simple theory of heat transfer, as applied to sand castings and described in the previous paragraphs, indicates the necessity for an accurate value of interface temperature for any calculation of solidification time.

It was decided, in the absence of a thoroughly reliable theoretical method of predicting the value or range of values, that this quantity would be experimentally obtained in castings of simple shape and of various sizes cast in three different alloys. This was done in order that convenient mean values might be derived for use in any subsequent calculations.

Although Ohira[32] has considered interface temperature as a function of time in determining the thermal conductivity of the mold, it was anticipated that any extension of this method would be arithmetically laborious.

The experimental measurement of interface temperature itself presents certain difficulties. The location and nature of the mold-metal interface itself is somewhat obscure. Several workers such as Pellini,[42,43] Gittus and Hughes[44] and Middleton and Protheroe[45] have defined it as the temperature indicated by means of a butt-welded, silica-sheathed thermocouple lying at the interface half within the mold and half within the cavity. The axis of such a couple was in the plane of the mold face. Ruddle[13,30] and his co-workers have preferred the use of twin-bore, refractory-sheathed thermocouples, the tips of which were lightly covered with alundum cement.

However, Atterton and Houseman[46] have shown the temperature-time relationship thus obtained differs considerably from that measured with a bare-wire, unjoined thermocouple. With this latter type of couple the insulation is discontinued just before emerging through the mold face so that the two wires separated by about 2 or 3 mm eventually have as their thermo-junction the penetrating liquid or the solidified metal skin. It would appear that such a system is not subject to the thermal lag of the former methods. The use of this latter method was preferred for the present experimental work.

Experimental Work

The alloys used were:

1) 12 per cent silicon, aluminum-base alloy (unmodified).
2) 8.5 per cent aluminum, copper-base alloy.
3) Gray cast iron of carbon equivalent 4.2 per cent.

Details of the metal analyses, thermal constants, etc., appear in the Table 1-2 together with details of experiments carried out. The alloys were chosen to cover a range of interface temperature ~500 C to ~110 C (~932 to 2012 F), but at the same time are of considerable interest because of their frequent use in founding. In the cases of silumin and aluminum bronze, the temperature was recorded using 28-gage chromel-alumel thermocouples connected through a selector switch to a square-wave amplifier-recorder unit of full scale deflections 20 and 2mv with a total response time of 0.2 sec.

The major part of the thermal emf was backed off. Thermocouples at the center of the castings were insulated by twin-bore porcelain refractory along their lengths, and by a thin wash of an alumina-water suspension at their ends. To prevent metal penetration, the twin-bore tubes were sealed off with alumina.

The hot junctions of the interface thermocouples were left unjoined,[46] and were intended to measure the metal "skin" temperature only. Their lengths were also porcelain insulated. For the castings made in cast iron the interface temperatures were measured using an accurate portable millivoltmeter. This had a response time of approximately 1 sec, and was shown to be accurate to ±1 C (±2 F). Thermocouples were again insulated but were also covered by thin steel sheaths which were alumina washed along their lengths.

Without the added mechanical protection couples invariably failed. The center thermocouples were all insulated at their tips by a somewhat thicker wash of alumina than that used with the other materials. The results of these experiments will be discussed separately for each alloy.

Aluminum-Silicon alloy. A series of spheres with diameters ranging from 1 to 4⅜-in. was cast into sand molds. The method of ramming was such that the ramming density gradients were minimized in the mold. No thermal gradient could be detected in the case of the smallest diameter sphere before, during or even after solidification. In the sphere of 1¼-in. diameter a gradient of 1 C (2 F) along its radius was detected immediately prior to completion of solidification. With spheres of 2 in. diameter upward,

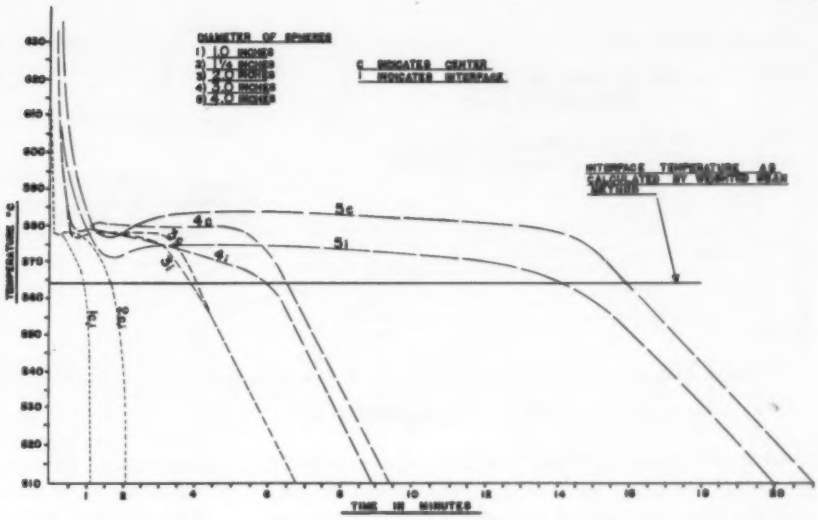

Fig. 1-5 — Temperature-time relationships in aluminum, 13 per cent silicon alloy spheres of various diameters.

radial temperature gradients were clearly discernible, and appeared to hold maximum values immediately prior to the completion of solidification.

The actual values of maximum radial temperature difference rose from 3 C (5.5 F) in the case of the 2 in. diameter sphere to about 15 C (27 F) in the case of the sphere of largest diameter (4 in.). The cooling curves obtained for the center and interface thermocouples are shown in Fig. 1-5. The approximate mean values for interface temperature cover a range of roughly 20 C (36 F). The minimum values are recorded for the largest sphere (4 in.), and the maximum for the fourth largest (2 in.). The fact that the small spheres had lower mean values of interface temperature, which was assumed to be coincident with that of the center, is due to a fundamental alteration in the shape of the cooling curve, which is no doubt due to the non-equilibrium solidification.

Cast Iron. Using a cupola-melted cast iron with a carbon equivalent approximately that of the eutectic composition, spheres of two sizes, 4⅜-in. and 3-in. diameter, were cast in green sand molds. The sand used in molding was a medium-grain naturally-bonded type. The maximum difference between interface and center temperature was not more than about 24 C (43 F) in either case. The cooling curves in Fig. 1-6 represent the averaged values of temperature meas-

TABLE 1-2 — PHYSICAL PROPERTIES OF ALLOYS INVESTIGATED

Alloy and Chemical Analysis	M.P. and Freezing Range, C (F)	Latent Heat, cal/gm	Density, gm/cc	Thermal Conductivity, cgs units	Specific Heat, cal/gm/°C	Casting Temp. C (F)	Casting Size Shape and Mold
12% Si (unmod.) remainder superpure Al., scrap remelted	584 (1085) 7 (13)	95•	2.42†	0.35••	0.259†	700 (1292)	Spheres 1 to 4⅜-in. diameter medium grade sand
8.5% Al, remainder electrolytic Cu, scrap remelted	1038 (1985) 0 (0)	55†	6.9†	0.1••	0.131†	1250 (2282)	Plate 1 x 6 x 6 in. thick fine and coarse sands
Cupola melted cast iron Average analysis: C 3.35% Si 1.98% P .53% S .11% M .70% (carbon equiv. 4.2%)	1150 (2102) (L) 1120 (2048) (S)	47[24]	6.8††	.09‡	0.212‡‡	1300 (2372)	Spheres 2 to 4⅜-in. diameter, medium-grade sand

(L) indicates liquidus
(S) indicates solidus

•Determined calorimetrically.
†Calculated by the Neumann-Kopp rule (See A.S.M. *Metals Handbook*, 1948).
••R. Ruddle and A. Mincher, *Jnl., Inst. of Metals 78*, p. 229, 1950-51.
††C. Schwartz, AFA TRANSACTIONS, *53*, p. 1, 1945.
‡J. Donaldson, Proc. *I.B.F. 32*, p. 125 (Extrapolation) 1938-9.
‡‡S. Unimo Toh. Imp. Univ. Sci. Rep. *15*, p. 331, 1926.
NOTE: Super figure refers to reference already listed.

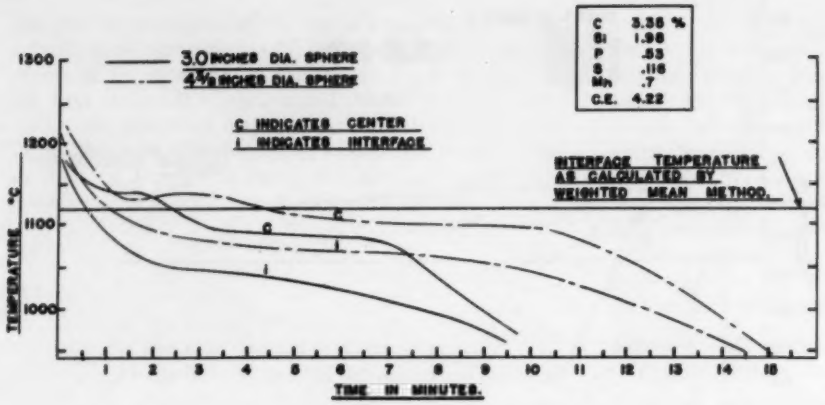

Fig. 1-6 — Temperature-time relationships of spheres in cast iron.

ured at 10 sec intervals for two series of experiments.

Aluminum Bronze. An 8.5 per cent aluminum, copper-base alloy was melted in a gas-heated crucible furnace, and cast in a variety of plate sizes between ¼-in. and 3 in. thick. Two sand types were investigated:

1) Fine sand, soft-rammed.
2) Coarse sand, hard-rammed.

Two spheres, 2-in. and 4⅜-in. diameter, were also cast. For the two thinner plates, no difference in center and interface temperature could be detected at any time during solidification. The experiments with the 1-in. thick plates indicated a maximum difference of 20 C (36 F) for both mold conditions (Fig. 1-7). Similarly, both mold conditions in the instances of the 3-in. block castings showed identical maximum temperature differences. It would seem that a maximum value of temperature is reached for only a small increase in casting size with this alloy.

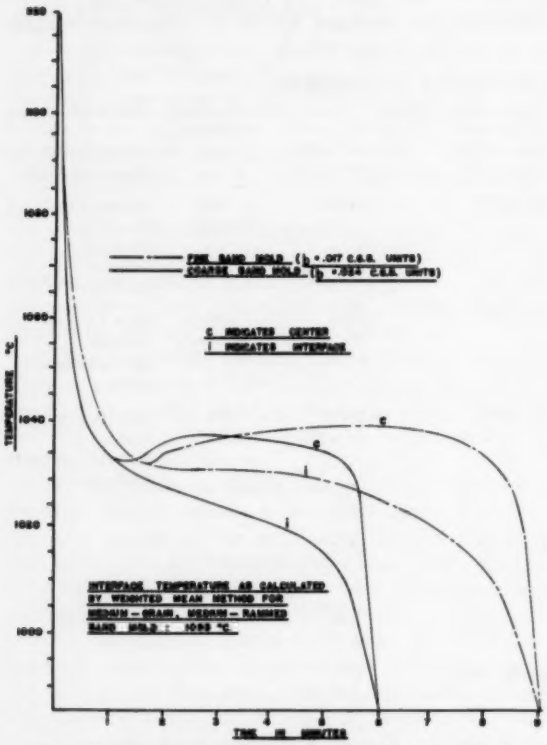
FINE SAND MOLD
COARSE SAND MOLD
C INDICATES CENTER
I INDICATES INTERFACE
INTERFACE TEMPERATURE AS CALCULATED BY WEIGHTED MEAN METHOD FOR MEDIUM – GRAIN, MEDIUM – RAMMED SAND MOLD : 1092 °C
TEMPERATURE °C
TIME IN MINUTES

Fig. 1-7 — Temperature-time relationships for aluminum bronze (8.5 per cent Al) plates 1 in. x 6 in. x 6 in., cast in molds of differing chilling power.

DISCUSSION OF RESULTS

The assumption of a constant, instantly attained value of interface temperature is only true for a limited range of casting sizes. The magnitude of this value appears to be always below the solidification temperature and not above it as predicted by the Riemann equation (2). Other proposed equations do, however, give a little better agreement. The increasing difference between interface and center temperature with increasing casting size is due to the fact that the solidified surface, which is cooling continuously below the solidification range, is influenced by the thermal blocking effect of the slowly solidifying center in varying degrees according to casting size.

Thus, in the instance of a large casting, thermal blocking of the center has less effect on the surface cooling. The obvious inference from this is the dependence of temperature difference between the center and interface on solidification temperature and temperature diffusivity of the metal cast. Considering the results for all the materials it might be thought that variation of maximum temperature difference depends upon 1) the casting size, 2) thermal diffusivities and 3) the difference between the initial mold temperature and some temperature lying between casting and solidification temperature of the alloy.

Thus, maximum temperature difference, for a particular mold condition results from a small increase in section with a casting medium of low diffusivity solidifying at a high temperature, or from a large increase in section with a casting medium of high diffusivity solidifying at a low temperature. Expressing this in the form of an equation for a particular type of sand mold, we obtain:

$$\Delta\theta_{MAX} = f\left[x'(\bar{\theta}_1 - \theta_0)\frac{a_2}{a_1}\right] \qquad (23)$$

where

$\Delta\theta_{max}$ is the maximum temperature difference.
X is the shortest distance between the center and the major surface of the casting.
$\bar{\theta}_1$ is the weighted mean temperature between pouring and solidification.

θ_o is the temperature of the mold.
α_1 is the mean temperature diffusivity of the metal.
α_1 is the mean temperature diffusivity of the mold.

The temperature $\bar{\theta}_1$ is taken as the weighted mean described previously. A general correlation between $\Delta\theta_{max}$ and the factor $[X(\bar{\theta}_1 - \theta_o): \alpha_2/\alpha_1]$ might be expected. Figure 1-8 gives evidence of the correlation, the scatter occuring is probably due to the not entirely reliable values of α_1 used.

In addition to the present results, certain data by Ruddle and Gittus and Hughes are also included in Figure 1-8. A possible second source of deviation of a lesser magnitude is to be found in the fact that the actual center temperature often drops gradually during solidification. Apart from the magnitude of the maximum temperature difference between the center and interface, the change of the shape of the interface temperature cooling curve with increase in section size is also to be considered.

Ruddle,[30] in investigating several eutectic alloys, suggested that three shapes of such a curve occurred, two of which were probably typical of eutectic alloys whose mechanism of solidification was not that of the skin formation generally associated with pure metals and eutectic alloys. However, since the shape of the interface temperature cooling curve approximates to each of these shapes in turn as the casting size is increased, it would appear that a physical interpretation in terms of temperature, diffusivities and section thickness is more appropriate than a metallurgical one.

GENERAL CONCLUSIONS

For the purpose of applying simple heat flow theory to the progress of solidification and total solidification time in simple sand-cast shapes, certain values of the thermal constants involved must be available. In addition, it is necessary to make certain assumptions so that the basic equations are applicable.

In the preceding section the validity of the assumptions has been discussed and, in one important case, examined experimentally, while the sources of available thermal constants have been collected. The present position in the application of the heat flow would appear to be governed by:

1) Assumption of constant, instantly attained interface temperatures. Here it has been shown that only an averaged value can be applied.
2) Inaccuracy introduced through the use of approximate thermal constants. Here there is little data available and a necessity for further work.
3) Inaccuracy introduced through several sources of heat loss, such as gates, flashes, mold corners, etc.

The first point, that of interface temperature, is indeed important. In view of the few attempts to apply theory in this field, mean values derived from experiment must be relied upon. Regarding the second point, only continued research involving costly apparatus can yield more data in the field of metals and alloys; data not only necessary in the field of solidification but also in other branches of metallurgy. The

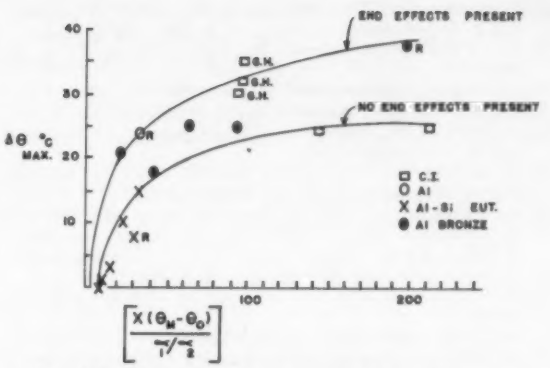

Fig. 1-8 — Correlation of $\Delta\theta_{MAX}$ and the group $\left[\frac{X(\bar{\theta}_1 - \theta_o)}{\alpha_1 / \alpha_2}\right]$

third and final point borders on the shaped sand casting. The mathematical analysis of all but the most simple shapes in terms of heat flow in sand molds often results in the most complex and sometimes insoluble expressions.

Consequently, the division of the casting and the risers into an assemblage of simple shapes A, B, C, D, etc., such that

$$t_{\circ}R > t_{\circ}A > t_{\circ}B > t_{\circ}C > t_{\circ}D, \text{ etc.}$$

and the subsequent application of the foregoing equations, must be accompanied by careful thermal analysis such as has been carried out by Ruddle[22] and Pellini and Bishop[47-50] and their respective coworkers.

The present authors feel that much can be gained from such a conjoint investigation and the testing of the simple heat flow theory, without resorting entirely to the empirical.

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APPENDIX

To facilitate use of various data cited in the current paper the following conversion factors are tabulated.

Parameter	Units A	Units B	Relation of A to B
Temperature	C	F	A = (B-32)5/9
Time, t	sec	min	A = B(60)
Time, t	sec	hr	A = B(3600)
Length	cms	in.	A = B(254)
Length	cms	ft	A = B(30.48)
Weight	gms	lb	A = B(453.59)
Area, A	cm^2	$in.^2$	A = B(6.4156)
Area, A	cm^2	ft^2	A = B(929.0)
Volume, V	cm^3 (cc)	ft^3 (cu ft)	A = B(28,317)
Density, ρ	gm/cc	lb/cu ft	A = B(1.602 × 10^{-2})
Density, ρ	gm/cc	lb/cu in.	A = B(27.68)
Quantity of heat, q	cal	Btu	A = B(252)
Specific heat, c	cal/gm/C	Btu/lb/F	A = B
Latent heat, L	cal/gm	Btu/lb	A = B(55.57 × 10^{-2})
Thermal Conductivity, k	cal/sec/cm^2/cm/C*	Btu/hr/sq ft/ft/F†	A = B(41.34 × 10^{-4})
Heat diffusivity, b $\left(=\sqrt{(k\rho c)}\right)$	cgs units	ft/lb/hr units	A = B(8.13 × 10^{-3})
Temperature diffusivity $\left(\alpha=\frac{k}{\rho c}\right)$	cgs units	ft/lb/hr units	A = B(25.52 × 10^{-2})

*Abbreviated frequently to cgs units.
†Abbreviated frequently to ft lb hr units.

PART II
SIZE AND SHAPE EFFECT ON SOLIDIFICATION TIME

INTRODUCTION

In Part I it was pointed out that progress in the application of heat flow theory to the problem of solidification of castings in sand molds depends, among other things, on the experimental verification of a number of currently used heat flow equations. Part II will describe and analyze some of the results that have been obtained with some simple shapes, namely, plates, cylinders and spheres. This work was carried out with two eutectic alloys, silumin (Al-Si eutectic) and cast iron, using a number of molding materials.

The accuracy of the equations, already derived by the authors in the first part

$$t_s = \frac{R^2}{\left[\frac{\sigma b_2 v}{2\rho_1 \bar{q}_1} + \sqrt{\frac{v}{\rho_1 \bar{q}_1}\left(\frac{\sigma^2 b_2^2 v}{4\rho_1 \bar{q}_1} + \frac{k_2}{C_1 C_2}\right)}\right]^2} \qquad (18)$$

for cylinders and spheres

$$t_s = \left(\frac{\rho_1 \cdot \bar{q}_1}{\sigma b_2 \cdot v}\right)^2 \cdot R^2 \qquad (19a)$$

for plates, together with the thermal constants fed into them, has been experimentally examined.

In order to make the text that follows clearer, results and experiments with each alloy are discussed separately.

EXPERIMENTAL WORK

Silumin Alloy

In order to limit experiments to a reasonable number, the three major variables, casting size, shape and mold condition were considered. Solidification times of castings were measured for the following sets of conditions:

a) Plates cast in dry sand molds of a medium-grained, medium-rammed synthetic sand.
b) Cylinders cast in dry sand molds of medium-grained, medium-rammed synthetic sand.
c) Spheres cast in green sand molds of medium-grained, medium-rammed synthetic sand.

Casting Sizes. The sizes of castings were as follows:

Plates ¼ x 6 x 6 in.
½ x 6 x 6 in.
1 x 6 x 6 in.
2 x 12 x 12 in.
Cylinders 4 in. high, diameters—0.6, 0.75, 0.85, 1, 1.5, 2, 3, 4, 5, 6 in.
3½-in. high, diameters—0.6, 0.85, 1, 1.5 in.
Spheres Diameters 1, 1.25, 2, 3, 4, 4.4 in.

Procedures

Melting Procedure. The alloy was based on super-purity aluminum, to which was added the requisite quantity of a high-purity temper alloy. The obtained scrap was subsequently remelted for castings within the series (plates, cylinders and spheres), any losses being made good with virgin alloy when necessary. Melting was carried out in a gas-fired crucible furnace. Casting temperature was 700 C (1292 F), and the metal was not allowed to exceed the temperature of 800 C (1472 F) in the furnace.

Molding Methods and Sand. Two distinct methods of molding were used, the first consisted of the use of a molding machine, which squeezed layers of sand that had been previously weighed into a suitable box. This method and the sand density distribution that it produces within the mold have been described previously.[1] The second method, which was used in making molds for the spheres only, consisted of the careful hand-ramming of similar layers around metal or wooden patterns. The molds for the cylinders were made by a method similar to the first, except that the cavities were cut out from the rammed sand by means of cylindrical steel shells.

The sand used was a 3½ per cent bentonite-bonded silica sand of medium grain size (distribution 60-180 B.S.S. No., 60-170 U.S.S. No.) and was rammed to a density between 1.4 and 1.5 gm/cc. After milling in a plough-type batch mill for 5 to 10 min, molding was immediately started. A moisture content of 3 per cent was maintained throughout. Drying for 8 to 10 hr at 200 C (392 F) then followed in the case of the dry-sand molds. Castings were made in the green sand molds not later than 20 min after assembly.

Gating and Pouring. The plate castings up to 1 in. wide were gated in the following manner—From a small pouring basin 2 in. in diameter and 2 in. deep, a ½-in. diameter runner led directly onto the top surface of the plate-shaped mold cavity at one of its corners. For the sake of symmetry and, in addition, to indicate approximately when the mold was filled, a cylindrical vent of exactly similar shape as the proper runner was made in the diagonally opposite corner of the mold. For the larger plate castings, the diameters of the runner and the vent were increased to ¾-in. The cylinders and all but two of the smallest spheres were bottom-gated, with channels which were of diameter not greater than one sixth the diameter of the casting. The two smallest spheres were top-gated.

Temperature Recording. Thermocouples used in the experiments were, a) 28 gage chromel-alumel type (sheathed within the mold cavity with twin-bore refractory tube along all but the last 3 mm of their lengths), for all castings except the large diameter spheres and the 2 in. thick plate, b) 24 gage chromel-alumel type, sheathed in thin tubular steel and insulated in a refractory powder. With both types of thermocouples the hot junctions and the last 3 mm of wire were coated with an alumina wash, thinly over the bead itself and slightly thicker elsewhere, so that penetration of the sheathing was prevented. The temperature-recording apparatus was of the pen-potentiometric type with a temperature accuracy ±2.0 C (3.8 F) and a full-scale deflection response of 1 sec.

Cast Iron

The cast iron experiments differed in certain respects from the experiments carried out with silumin. Such differences will be briefly described, all other experimental details being identical to those of silumin.

Casting Sizes. Sizes of castings were as follows:

Plates ¼ x 6 x 6 in.
½ x 6 x 6 in.
1 x 6 x 6 in.
2½ x 12½ x 14½-in.
Spheres Diameters 2, 3, 4, 4⅜, and 10½-in.

Materials Cast. Castings were poured in three irons, cupola-melted in a gray iron foundry. The compositions were as follows:

1. High-phosphorus gray iron (common engineering grade) C-3.5; Mn-0.4; Si-2.5; P-1.7; and S-0.12 per cent.
2. Medium-phosphorus gray iron (hydraulic castings grade) C-3.35; Mn-0.70; Si-1.98; P-0.53; and S-0.12 per cent.
3. Medium phosphorus inoculated iron (high-duty castings grade) C-3.25; Mn-0.17; Si-1.49; P-0.5; S-0.1; and Cr-0.05 per cent.

Molding Methods and Sand. The molding sand was a medium-grained, naturally-bonded red Bunter deposit sand. For all the castings made, two-part molds were used. In the case of plates, the drags contained the mold cavities. Initial experiments showed no significant difference between solidification time of castings made in molds compacted by a sandslinger, and those made by an experienced molder which were rammed to as near constant hardness as possible. Subsequent experiments were carried out using the hand-rammed type of mold. The green sand density was of the order of 1.6 gm/cc and the moisture content maintained at 5 per cent.

Gating and Pouring. The plates were gated in the same way as for silumin. The spheres were all top-gated except for the largest, which was side-gated.

Temperature Recording. The two types of thermocouple discussed in the silumin experiments were again used. The pouring temperature in both silumin and cast iron was measured in the ladle by means of a Pt/13 per cent Rh Pt thermocouple, also potentiometrically or with a quick-reading millivoltmeter.

CALCULATIONS DATA USED

Density of the liquid metals was taken as 2.42 gm/cc at 700 C (1242 F) for a eutectic aluminum-silicon alloy,[2] and 6.8 gm/cc at 1300 C (2372 F) for gray cast iron (hypoeutectic iron).[3]

Specific heat of the liquid metal and the latent heat at solidification for aluminum-silicon alloys are not

TABLE 2-1 — TEMPERATURES OF SOLIDIFICATION, POURING, FILLING AND AT THE MOLD-METAL INTERFACE

Temp. of	Temp. C (F) for Type of Iron: High - P (C.E. 4.9%)	Med. - P (C.E. 4.2%)	Med. - P Inoculated (C.E. 3.9%)	Reference
Liquidus	1182 (2156)	1221 (2228)	1232 (2246)	8
Solidus	1138 (2084)	1138 (2084)	1138 (2084)	8
Liquidus	1380 (2516)	1140 (2084)	1165 (2129)	obtained from
Solidus	1130 (2066)	1130 (2066)	1130 (2066)	equ. dgm.[8]
Liquidus	1127 (2057)	1175 (2147)	—	9
Solidus	1110 (2030)	1130 (2066)	—	9
Liquidus	1120 (2048)	1148-1160 (2102-2240)	1186 (2165)	this study
Solidus	1110 (2030)	1120-1130 (2048-2066)	1125 (2057)	this study
Pouring	1300 (2372)	1300†† & 1360•• (2354 & 2480)	1340 (2444)	this study
Ave. on filling of castings:				
plates	1290 (2354)	1290 (2354)	—	this study
spheres	—	1200‡, 1240‡‡• (2192, 2264) 1200‡ (2264)†	1240 (2264)	this study
Ave. at interface during solidification	1040 (1904)	1060 (1940)† (overall mean)	1055 (1931)	this study

•dry sand mold.
†green sand mold.
••spheres only.
††plates and spheres.
‡spheres poured at 1300 C (2354 F).
‡‡spheres poured at 1360 C (2480 F).

readily available in the literature. However, the latent heat may be calculated:

a) From the density of the solid at the melting point,[4] for 11 per cent Si it is equal to 109 cal/gm; and for 13 per cent Si, equal to 123 cal/gm.
b) From an entropy calculation for 12 per cent Si it is equal to 65 cal/gm.
c) An experimental (calorimetric) determination by the authors for 12 per cent Si gave the value of 95 cal/gm.

This last value was used in the light of disagreement between (a) and (b).

The latent heat of solidification of gray cast irons is similarly difficult to obtain accurately. However, a value of 47 cal/gm is given in the literature[5] for a typical gray iron.

The specific heat of liquid aluminum-silicon eutectic can be calculated by means of the Neumann-Kopp rule[2] on the assumption that this is valid for eutectics. The value obtained is 0.259 cal/gm/°C.

The specific heat of the liquid cast iron was taken as that given by Unimo[6] for a typical gray iron: 0.212 cal/gm/°C.

Temperatures Recorded

Temperatures of pouring, filling, solidification and at the mold-metal interface are briefly given below.

a) For aluminum-silicon, the pouring temperature was 700 C (1242 F), with an allowance of 10 C (50 F) made as a pouring loss. The temperature of solidification was taken as that of the liquidus.[2] The temperature at the interface was taken as that indicated by a modified form of the Riemann equation,[7] this value having been shown to be close to the measured values (Part I).
b) For cast irons, supplementary experiments reported in Part I with center and interface thermocouples gave the results in Table 2-1, which are compared with the existing values from the literature.

The disagreement between observed and calculated interface temperature is serious and presumably due to the unsuitability of the α_1 term for cast iron in the equation used.

Thermal Properties of the Molds

Aluminum-Silicon Eutectic. For dry sand molds the mean heat diffusivity b_2 was calculated from data of Atterton,[10] who gives the thermal conductivity k_2 at various temperatures in a similar sand, and data of Ohira[11] for mean specific heat.

$$b_2 = 0.0150 \text{ cgs units}$$
$$k_2 = 0.0006 \text{ cgs units}$$

For green sand molds, Ruddle and Mincher[12] have given the value for the mold constant $\sigma v b_2$ under conditions similar to those of the present experiments. The mean heat diffusivity b_2 was calculated from this constant. In turn, the mean thermal conductivity k_2 was calculated from b_2 using the expression of Ohira[11] for the specific heat of a green sand.

$$b_2 = 0.022 \text{ cgs units}$$
$$k_2 = 0.0011 \text{ cgs units}$$

Cast Irons. The mean diffusivity of the sand used (in its dry state) was calculated from data obtained by the authors:[1]

$$b_2 = 0.019 \text{ cgs units}$$

The mean thermal conductivity was again calculated from the relation

$$b_2 = \sqrt{k_2 \rho_2 c_2}$$

where c_2 was taken from Ohira's data

$$\rho_2 \ 1.6 \text{ gm/cc and}$$
$$k_2 = 0.008 \text{ cgs units.}$$

The volume to surface area R, for the cases of spheres, plates and cylinders whose major dimensions were at least six times their minor dimensions, was calculated ignoring the end effects. However, for all other castings (i.e. those deemed to exhibit the corner effect) the ratio of volume to effective surface area R' was calculated from the method and data of Ruddle and Skinner.[13]

DISCUSSION OF RESULTS

It has been shown in the preliminary discussion of the heat flow equations (Part I) that castings in the three basic shapes used, with volume-to-surface ratio and all other factors being equal, solidify at different times. However, the difference between the solidification time of a wide plate and that of a sphere is greater than the difference between those of a sphere and a long cylinder, all other factors being equal. This point is best illustrated diagrammatically by means of a log plot of volume-to-surface ratio R against solidification time t (Fig. 2-1).

The effect of other factors such as mold medium, casting alloy, temperature of mold or temperature of solidification of castings are also best illustrated in the same manner (Figs. 2-2 to 5). The experimental results, together with the calculated relationships for the three sets of experiments, are shown in Figs. 2-6 to 2-14.

Aluminum-Silicon Eutectic

Probably two of the important assumptions made in the application of simple heat flow theory to the present problem were a) the assumption of a mean interface temperature for a range of castings in dry sand and green sand molds and b) the assumption that the drying out phenomenon,[1] which reduces the apparent thermal conductivity k_2 of the mold with time, is not so effective at a lower interface temperature as it is with that of, for example, aluminum-bronze,[1] i.e., that mean value for the lower temperature range can be inserted in equations (18) and (19).

The first assumption stands or falls on the experi-

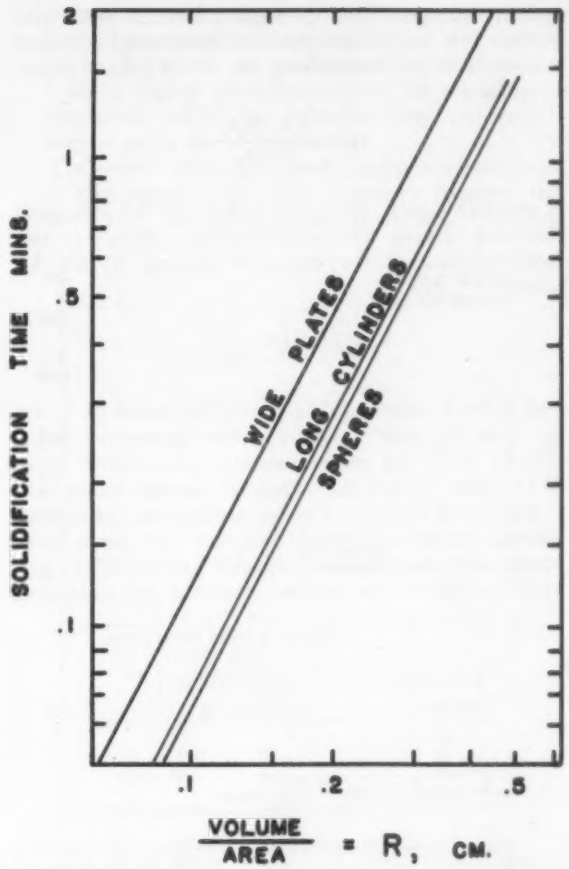

Fig. 2-1 — Casting shape effect on solidification time.

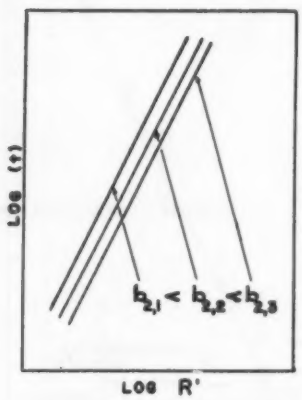

Fig. 2-2 — Mold material effect on solidification time ($\bar{q}_1$, θ_i and θ_o assumed unchanged).

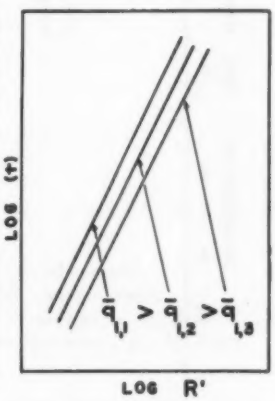

Fig. 2-3 — Total heat content effect per gram of molten metal on solidification time (b_2, θ_i and θ_o assumed unchanged).

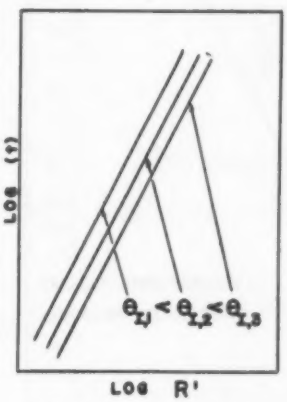

Fig. 2-4 — Interface temperature effect on solidification time (b_2, $\bar{q}_1$ and θ_o assumed unchanged).

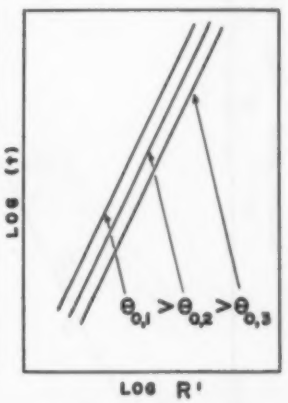

Fig. 2-5 — Mold temperature effect on solidification time (b_2, θ_i and $\bar{q}_1$ assumed unchanged).

mental evidence. This question has been dealt with in Part I. It was shown that the mold-metal interface temperature, as determined by the Riemann equation (2),

$$\theta_i = \frac{\theta_1 b_1 + \theta_2 b_2}{b_1 + b_2}$$

is unreliable as it takes no account of the total heat liberated during the solidification. However, two modifications of the equation—writing b_1^1 for b_1, where

$$b_1^1 = \sqrt{K_1 \rho_1 \left(c_1 + \frac{L_1}{\theta_m}\right)}$$

and θ_1^1 for θ_1, where θ_1^1 is the weighted mean of θ_c and θ_m (Part I), give a rather better agreement 563 C (995 F) with the experimentally determined mean 574 C (1067 F) for the range of castings concerned.

Regarding the second major assumption, when comparing temperature distribution[12] for green sand molds with interface temperatures 548 C (1022 F) and 1083 C (1985 F), the following points are indicated:

Time After Casting, min	Depth of Mold (mm) above 100 C (212 F)	
	548 C* (1022 F)	1083 C* (1985 F)
5	13	25
10	29	37
20	44	48

*Nominal interface temperature

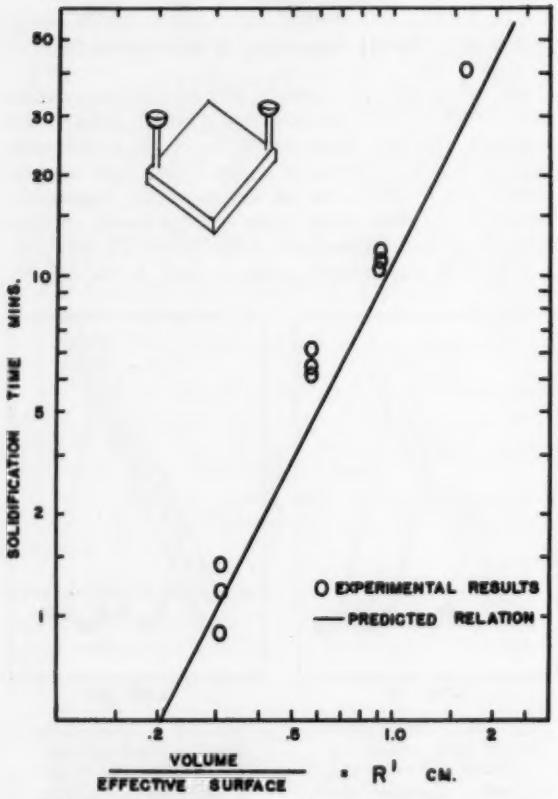

Fig. 2-6 — Silumin plates in dry sand molds.

These data confirm that initially the speed of drying out is slower in a mold where a lower interface temperature is maintained. This permits the use of the approximate mean heat diffusivity value for the green sand in calculations of solidification times of castings with volume-to-surface-area ratios below about 25 mm. The agreement is seen clearly in Fig. 2-11.

Unfortunately, an assessment of accuracy for the spheres cast in green sand is impaired by the assumption that a 10 C (18 F) temperature drop occurred in both of the gating systems. It appears that with more quiescent methods of pouring this is approximately true (i.e., with plates and cylinders). However, the more turbulent gating methods, which were used for the spheres, no doubt result in higher temperature losses. Further experimental work will be needed to consider the possible variation of heat transfer in the liquid metal with varying degrees of turbulence reported by Chvorinov[14] in a recent literature review.

R to t Relationship

The calculated relationship of R to t for the castings in dry sand molds are slightly below the experimental points in each case. This is possibly due to inaccuracy of the specific heat value calculated by the Neumann-Kopp rule. The agreement of slopes indicates justification of assuming a mean interface temperature for the particular range of castings used. The scatter of experimental points, which seems to be more pronounced in this alloy than in others which were investigated, may also be partly due to compositional changes through scrap melting.

When the three series of experiments are examined, with due consideration to the assumptions made in

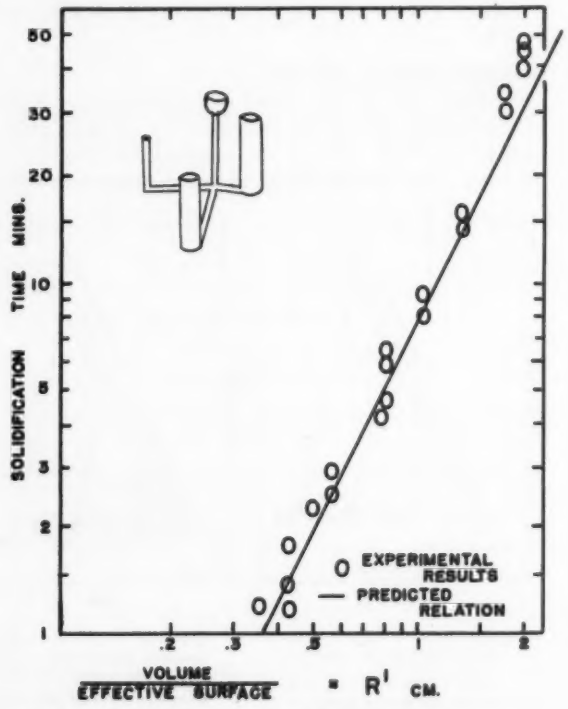

Fig. 2-7 — Silumin cylinders in dry sand molds.

applying simplified heat flow theory, the following comparison results:

Shape	Sand Mold	Discrepancy between calculated and experimental result, % Ave.	Max.	Min.
Plates	Dry	23	40	0
Cylinders	Dry	13	40	0
Spheres	Green	18	50	0

Cast Irons

1) Plates of a medium phosphorus ("hydraulic") iron (C.E. 4.2 per cent) cast in green and dry sand molds. The results of these experiments are found in Fig. 2-8. The solid line represents the relation predicted by equation (19) for dry sand mold castings. The broken line connects the experimental points for green sand mold castings. The agreement between theory and experiment is reasonably good in this case. It is also interesting to note the disappearance of the increase in chilling power brought about by the presence of moisture in the sand as the casting section increases.
2) Plates of a high phosphorus iron cast (C.E. 4.9 per cent) in green sand molds. In a recent paper Gittus and Hughes[9] have shown, by comparing the results of thermal analysis with those obtained by quenching, that in certain irons (particularly the higher phosporus type) eutectic solidification is still proceeding below the knee of the time-temperature curve. In fact, it may probably continue to do so until the commencement of the phosphide eutectic solidification. However, the work would seem to justify the assumption that the knee represents the end point of solidification for all but a small percentage of the mass of the casting.

Figure 2-9 shows the predicted relation of R and t for a higher phosphorus iron, in addition to that predicted for the hydraulic iron, and experimental points for both materials.

The points plotted, marked p represent the knees of the curves (Fig. 2-10). Disparity between the theoretical and experimental relationship has un-

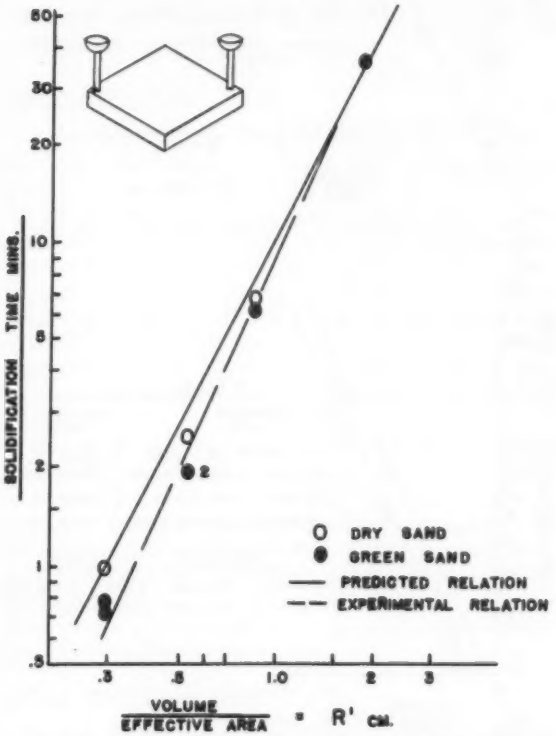

Fig. 2-8 — Gray iron plates, 4.2 per cent C.E. (hydraulic iron).

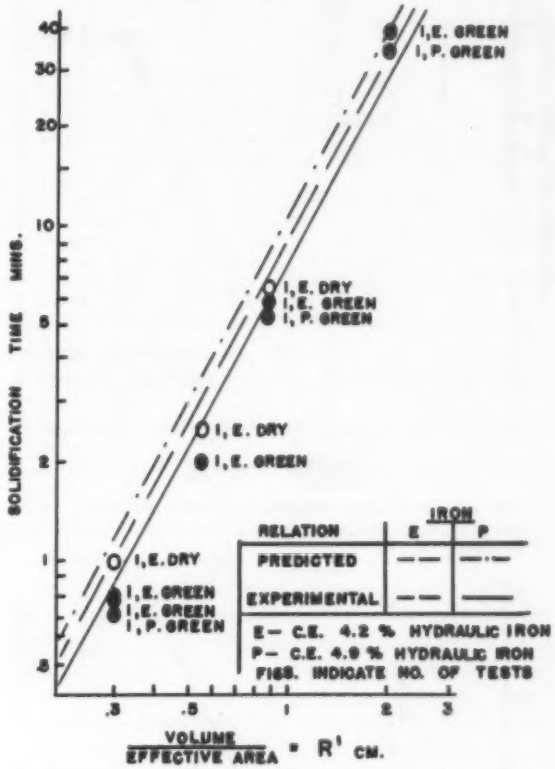

Fig. 2-9 — Gray iron plates in green and dry sand molds, irons E and P.

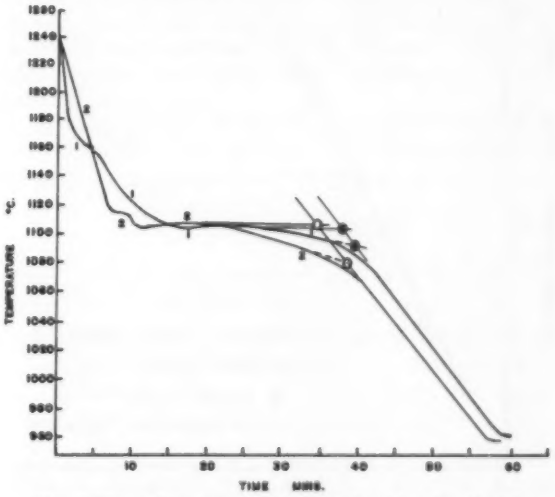

Fig. 2-10 — Time temperature relationships for 1) 4.2 per cent C.E. (hydraulic iron) and 2) 4.9 per cent C.E. (high phosphorus iron). Tangents drawn to give range of values of t_s.

doubtedly been caused by the difficulty in fixing an end-point of solidification for the iron of high phosphorus content.

3) Spheres of medium phosphorus (hydraulic) iron cast (C.E. 4.2 per cent) in green and dry sand molds. In Fig. 2-12 the theoretical relation for a given filling temperature for the hydraulic iron cast in dry sand molds is plotted as a solid line. Experimental points show a good agreement. It is interesting to note that, as before, only for the castings of small section (example, 2 in. diameter) has moisture had any prolonged effect on mold chilling power.

4) Spheres of medium phosphorus, inoculated (high-duty) iron (C.E. 3.9 per cent) cast in green sand molds. Figure 2-13 shows the theoretical relationship for the above iron, and agreement between theory and experiment is quite satisfactory.

5) Spheres of medium phosphorus hydraulic iron (C.E. 4.2 per cent) cast in dry and green sand molds at two pouring temperatures. The theoretical relationships drawn in Fig. 2-14 are 1) broken line—hydraulic iron, max. temp. in mold 1240 C (2264 F) and 2) solid line—hydraulic iron, max. temp. in mold 1200 C (2192 F). These correspond

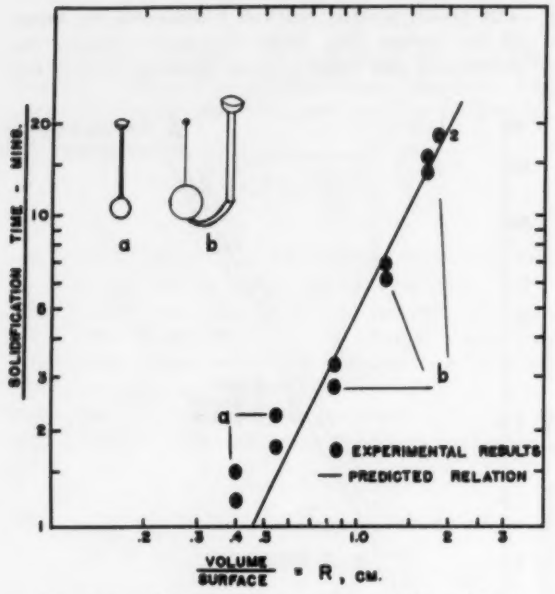

Fig. 2-11 — Silumin spheres in green sand molds, a) top-poured, plain ingate, b) bottom poured, reversed horngate.

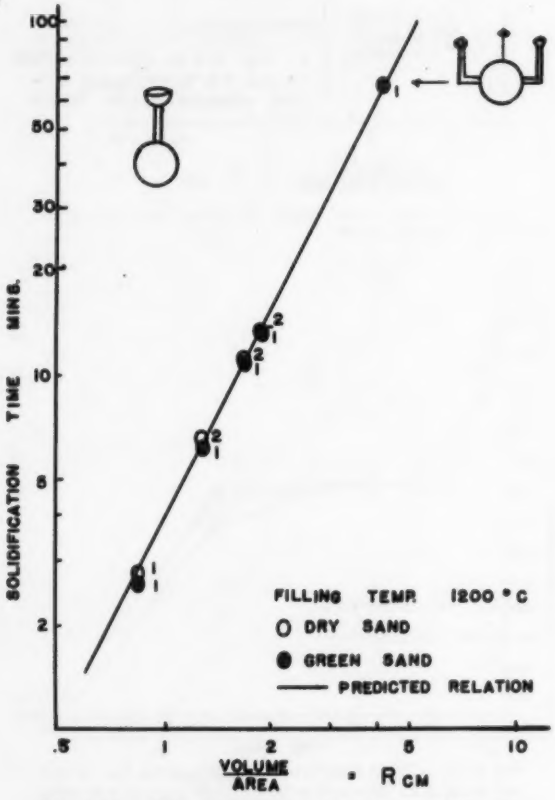

Fig. 2-12 — Gray iron spheres, 4.2 per cent C.E. (hydraulic iron).

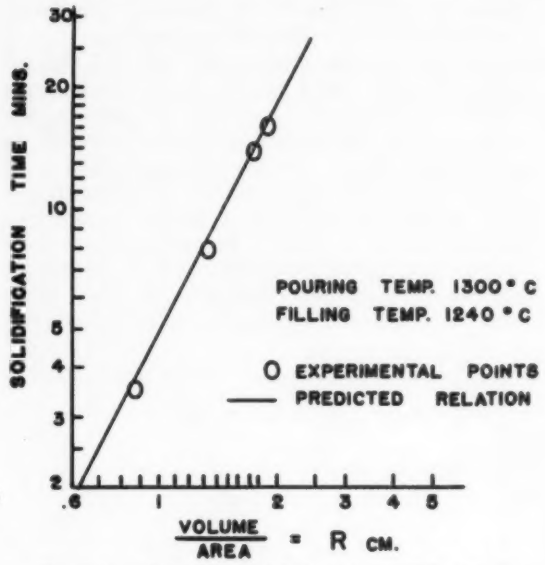

Fig. 2-13 — Spheres of high-duty iron (C.E. 4.9 per cent).

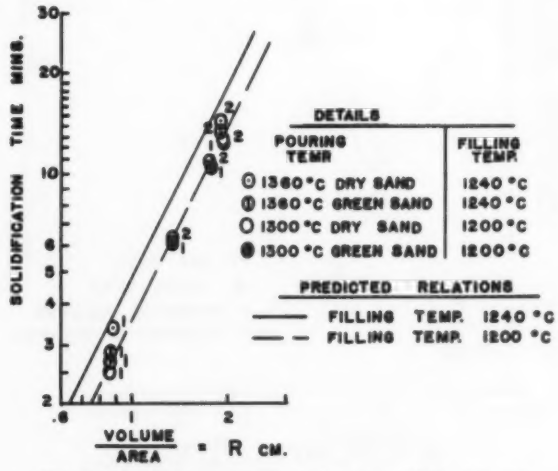
SOLIDIFICATION TIME MINS.
DETAILS
POURING TEMP
FILLING TEMP
1360 °C DRY SAND 1240 °C
1360 °C GREEN SAND 1240 °C
1300 °C DRY SAND 1200 °C
1300 °C GREEN SAND 1200 °C
PREDICTED RELATIONS
FILLING TEMP. 1240 °C
FILLING TEMP. 1200 °C
VOLUME / AREA = R CM.

Fig. 2-14 — Spheres of hydraulic iron (C.E. 4.2 per cent).

to the two pouring temperatures 1360 C (2480 F) and 1300 C (2372 F), respectively, for dry sand molds. The experimental points shown include those mentioned subsection 3 (above) of this discussion. The results obtained for castings of two sphere sizes poured in green and dry sand molds at the higher temperature would seem to indicate the possible importance of moisture during the mold swilling action immediately prior to the onset of solidification.

On the basis of these latter results, further attention is justified to the phenomena of turbulence in deep castings to be carried out conjointly, if possible with study of the effect of gating systems on the temperature loss.

CONCLUSIONS

As a guide to calculation of progress of solidification times as applied to soundness problems, the following conclusions can be drawn for the range of mold shapes and metal temperatures examined.

1) Mold cavity shape, heat content of the casting, mold metal interface temperature and temperature and thermal properties of the mold have been shown to shift vertically the $\log \cdot t$-$\log \cdot R$ relationship.
2) The solidification time of three simple shapes and the three alloys used can be calculated with reasonable accuracy, provided certain assumptions are made regarding temperatures at the mold-metal interface and of the casting immediately after pouring. Castings such as plates (side or edge gated) exhibit minimum turbulence losses of 10 C (50 F) whereas naturally deep castings which are top-gated (e.g., the cast iron spheres) exhibit a maximum loss (example, 100 C (180 F) in cast iron spheres). Quiescently poured shapes (example, bottom-poured cylinders) would appear to have a minimum loss of a similar order to that in plate castings, 10 C (18 F).

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PART III
MOLD MATERIAL EFFECTS

INTRODUCTION

It has been emphasized (Parts I and II) that there exists a considerable dearth of data on the various thermal constants involved for simple heat-flow calculations in castings. It has been shown[1] that a wide range of solidification times exists for a standard side-run 6 x 6 x 1 in. plate casting molded in various types of sands. The object here is, first, to interpret these results in terms of chilling power, or the mean heat diffusivity b_s of the mold. For this purpose further experiments, not previously published, were performed, involving temperature measurements in sand molds.

Second, from the values of b_s thus obtained, the prediction of solidification times for various plate castings in the three types of mold materials has been made. In addition, further information has been obtained on a) the movement of moisture in green sand molds and its subsequent effect on chilling power, and b) the feasibility of computing dry sand mold chilling power from a knowledge of the grain size distribution and certain other factors.

MOLD CHILLING POWER

In Part I the information referring to mold chilling power has been summarized. The majority of the methods practiced involved the measurement of sand temperatures.[2-4] It was decided that the data already published[1] should be re-examined to obtain the values of the chilling power, using solidification time of actual castings, in conjunction with the metal temperature measurements taken at the same time.

Chilling power may be conveniently expressed as the mean heat diffusivity of a mold b_s, where b_s is given by $\sqrt{k_2 \rho_2 c_2}$ where k_2, ρ_2 and c_2 are the mean values of thermal conductivity, ramming density and specific heat of the molding material in the range of temperature considered, namely, between room temperature and the liquid metal temperature of the casting.

By consideration of the simple heat flow theory it has been shown that the heat conducted away from a wide plate of area $2A$ in time t_s is given by:

$$q = (2A) b_2 (1.13) (\theta_i - \theta_0) \sqrt{t_s} \qquad (1b)$$

where some of the characters have already been defined (Part I) and, in addition,

θ_i indicates interface temperature (at the wide plate-mold face interface).
θ_o indicates initial temperature of the mold (generally room temperature).

However, it has also been shown that the temperature of the mold metal interface changes during solidification. Consequently, this quantity must be either measured or calculated by some empirical or theoretical method. The unreliability of theoretical

methods (Part I) prompted the authors to carry out careful experimental measurements of this quantity. Two extreme molding sands were considered, one a coarse-grained and the second a fine-grained sand.

Details of the experimental measurements, and a graph showing the time-temperature relationship were discussed (Part I). From this work and the results of interface temperature measurements for several other sand conditions, a mean value for interface temperature was obtained:

$$\theta_i = 1020\ \text{C}\ (1868\ \text{F})$$

for the material currently being considered (aluminum bronze). If we equate the amount of heat absorbed by the mold as given by equation (1b) with amount of heat liberated on solidification we have:

$$(\text{mass})\,[(\theta_i - \theta_m)\,c_1 + L_1] = (2A)\,b_2\,(1.13)\,(\theta_i - \theta_0)\,\sqrt{t_s} \qquad (1c)$$

where

θ_1 = temperature of metal within the casting immediately after filling mold.
θ_m = temperature of solidification.
c_1 = specific heat of the liquid metal.
L_1 = latent heat of solidification.

Thus, when the necessary temperatures and physical constants are known, the mean heat diffusivity may be calculated from the solidification time t_s. Experimental measurement of the temperature of the metal within the mold cavity on pouring showed this figure to be within 8 to 10 C (46-50 F) of the pouring temperature for this particular casting.

Corner Effects

In equating the amount of heat absorbed by the mold with that liberated by the solidification of the casting, it has been assumed that no heat is transmitted from the casting through either the side walls of the mold cavity or through the gating system.

Ruddle and Skinner[5] have shown that the effect of side walls or, more specifically, corner effects can be dealt with in the following way.

By measurement of the mold temperature distribution around various types of corner for several casting media, these workers were able to derive numerical factors connecting the actual geometrical area of a corner portion and their effective plane area. Thus, by this method an effective plane area for the whole mold face A' has been calculated, and is used instead of $2A$ in equation (1c).

Finally the heat lost through the gating system was estimated by means of a thermal analysis method which is described in the Appendix to this section. The numerical value of the heat so lost was found to be 30.5 cal/sec of solidification time.

The chilling power b_s of the various dry molding sands can also be calculated from the properties of the sand. This method is due mainly to Russell[6] and Eucken,[7] who have shown that the apparent thermal conductivity of a porous refractory material k_a, such as sand, can be calculated from the conductivity of its pores k_p (i.e., air) and the porosity fraction P.

The relationship derived can be conveniently approximated to:

$$k_a = k_p\left(\frac{3}{p} - 2\right) \qquad (20)$$

However, a correction must be made at higher temperatures for radiation through these pores. Russell, correcting for this, gives the equation:

$$k_p = k_t + (5.44 \times 10^{-12})\,T^3\,X \qquad (21)$$

where

k_t is the thermal conductivity of air, in cgs units[6-8]
T is the absolute temperature in °K.
X is the pore space diameter in cm.

Bell[9] has given an approximation for pore space diameter for a two-sieve distribution sand.

More recently Gittus[10] has extended this method to sands of any distribution. This method utilizes the area A_c under the cumulative distribution curves[1] in the following way:

$$X = \frac{200\,[\rho_{SiO_2} - \rho_B]}{3A_c\,\rho_B}$$

where

A_c is in gm.cm.
ρ_{SiO_2} is the true (solid) density of silica in gm/cc.
ρ_B is the ramming or bulk density of the aggregate.

This method of obtaining the average pore space diameter X has been preferred in the present investigation.

Figure 3-1 shows the results obtained from equations (20-22), together with those obtained by the Institute of British Foundrymen, as b_s, the mean heat diffusivity, plotted against ρ_2, the ramming density. The data derived for b_s from the results of Atterton[9] are also included. It is to be noted that the results derived from the above,[9] are not the simple arithmetic means of the room temperature and casting temperature values but integrate means, as the variables concerned (ref. 6 and equation 21) are directly related to the cube of the absolute temperature.

It should also be noted that the figure for b_s of green sands shown on the graph apply strictly to molds with castings of 1-in. thickness, and that the mean heat diffusivity b_s plotted applies to castings solidifying in the temperature range 1000-1200 C (1832-2192 F).

MOLD CHILLING POWER AND CASTING SOLIDIFICATION TIME

It has been shown that the solidification time of a wide plate is given by:

$$t = \left(\frac{\rho_1\,\bar{q}_1}{\sigma\,b_2 v}\right)^2 R'^2 \qquad (19b)$$

where

R′ is the ratio of volume to effective surface area.
ρ_1 is the density of the liquid metal.
σ is the constant 1.128.

$$v = \theta_i - \theta_o.$$
$$\bar{q} = [(\theta_c - \theta_m) c_1 + L_1]$$

It might be expected for green sands and green or dry sands containing combustible material that b_2 changes with increasing casting thickness, due to the drying and burning-out phenomena described.[1] Similarly, the value of θ_i (the average temperature of the mold-metal interface) also changes with casting thickness. This latter possibility has been examined in certain preliminary experiments (Part I), and thus a mean value of θ_i for a large range of casting thickness has been evolved — $\theta_i = 1020$ C (1868 F).

Since there is no readily available method of predicting chilling power of green sand mold or molds containing combustible materials, it was decided to compare the results for these materials with those for similar dry sand molds.

A convenient way of showing the relation of t (solidification time) to R' (or the ratio of volume to effective surface area) as expressed in equation (19) is to plot log t against log R'. The relationship thus obtained is a straight line of slope 2, intersecting the line R' = 1.0 cms at

$$t = \left(\frac{\rho_1 \bar{q}_1}{\sigma b_2 v}\right)^2 \text{sec}$$

Thus, providing that the physical constants and other quantities in the above relation are known, the

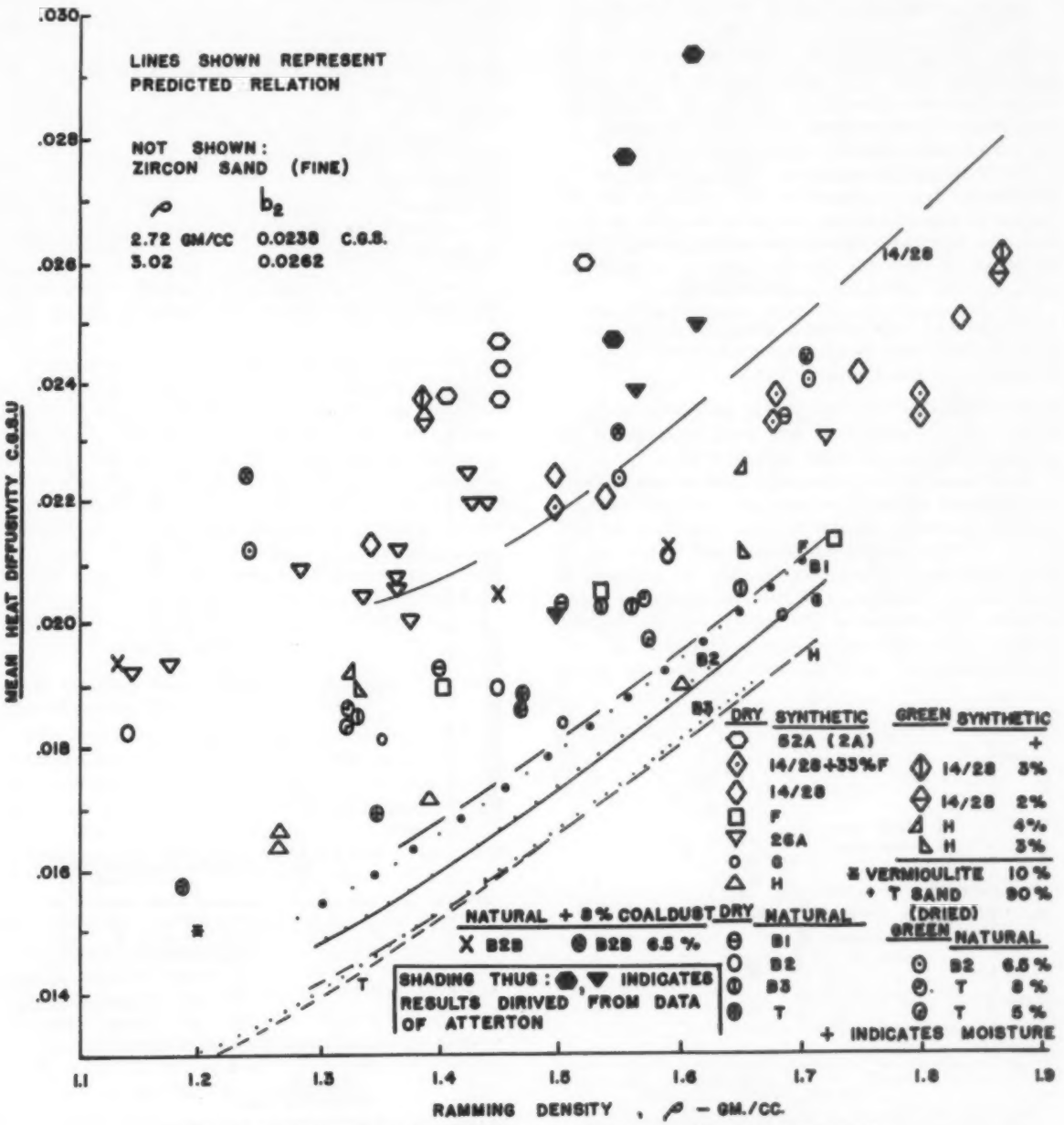

Fig. 3-1 — Relationship of heat diffusivity b_2 to ramming density ρ_2 for various sands.

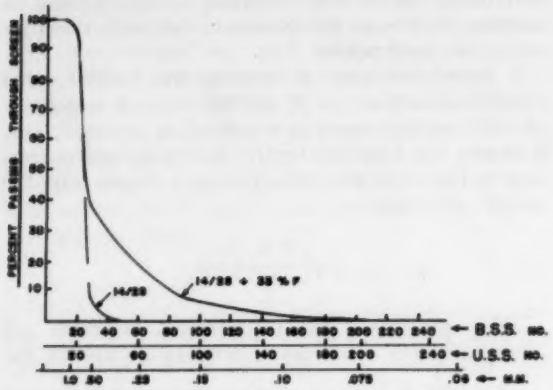

Fig. 3-2 — Effect of adding 33 per cent F sand to 14/28 sand.

line connecting R' and t is readily drawn on double logarithmic paper. The values used for L_1, c_1 and ρ_1 were calculated, (Part I). In the absence of accurate, experimentally determined data, these calculated values must be used as a first approximation.

The relationship obtained, together with the experimental data, is shown in Fig. 3-4. Only for the thicker section castings in fine sand has account been taken for heat losses through the gating system, as only for these castings did the loss become of great importance. The sand conditions studied were:

1) Coarse sand, hard rammed, dried.
2) A medium sand, medium rammed, dried.
3) Fine sand, soft rammed, dried.

Sands containing moisture (green) and one containing 8 per cent superfine coal dust were investigated for casting thicknesses between ¼ and 3 in.

In addition to the temperature measurements made, the diffusion of moisture was also observed using a method somewhat similar to that described by Gittus.[11] Thermocouples accommodated in the mold were here used as potential probes, in addition to their normal function. This method allows the measurement of resistance at the points near the thermocouples semi-continously. Since resistance is intimately connected with moisture content, the movement of a moisture wave with time can be shown graphically. The results of all the above experiments are shown in Figs. 3-4, 5, 6, 7, 8 and 9.

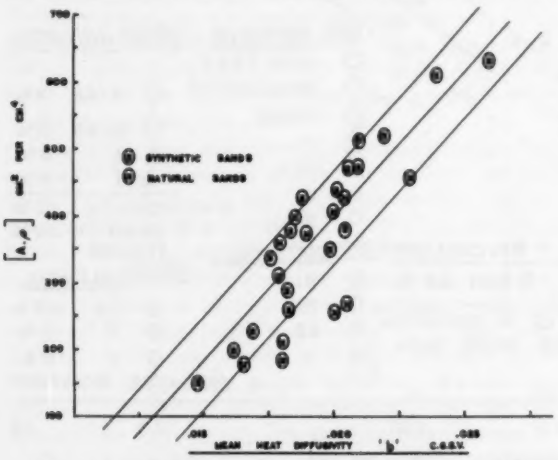

Fig. 3-3 — Correlation of mean heat diffusivity b_2 and the product of density ρ_2 and the Gittus factor A_c.

DISCUSSION

Chilling Power of the Mold

The relationship of chilling power b_2 to ramming density ρ_2 for all the sands examined is typified by a curve of positive slope. Both the slope and the vertical displacement of such a relation appear to be changed, respectively, with average grain size and grain size distribution of a sand.

The following generalizations can be made:

1) Chilling power b_2 increases with increase in ramming density ρ_2.
2) b_2 increases with increase in average grain size of sand.
3) Rate of change of b_2 with ρ_2 is dependent on the length of the "tail" of the grain size distribution (Fig. 3-2), i.e., the gradient decreases with the addition of fines.
4) For the casting thicknesses used, green sand has high values of b_2.
5) Addition of combustible material increases the value of b_2 for the sands with the particular casting thicknesses used.

The change in chilling power b_2 with average grain size, grain size distribution and ramming density has

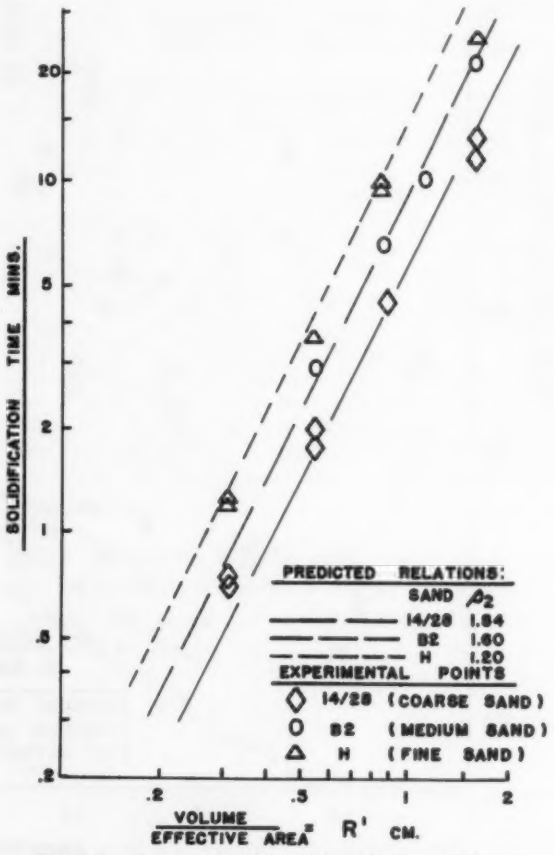

Fig. 3-4 — Log t — log R' relationship for aluminum-bronze plates.

been explained along the lines put forward for the corresponding change in solidification time t considered in ref. 1.

Figure 3-1 also includes the points derived from the results of Atterton.[4] It is to be noted that:

1) The results of Atterton expressed as b_s versus ρ_s show a rather steep gradient, much steeper than any of the results derived from measurements of solidification times.
2) The values of 26A and 2A sands (which should be directly comparable to those of Atterton for 26A and 52A sands) are of a lower order than the values of Atterton.

It is possible that the single squeeze ramming methods which were used,[4] and the steep density gradients associated with this type of ramming have, in fact, displaced the results. This is not altogether unlikely, and is further inferred when one considers the results predicted, using equations (20-22) which, although they are only approximations,[11] do indicate a less steep slope than the figures derived from ref. 4.

The unsuitability of the wholly theoretical method for smaller grain size sands has been suggested[11] to be due to changes in condition of contact. Further, it was suggested that the formation of domains (i.e., the grouping of the small grains within the substantial coating of clay bond) takes place. This may probably explain the change in appearance of fine sand when first the bentonite bond and then water are added to it in the mill.

It was thought that considerable use could be made in practice of curves connecting mean heat diffusivity b_s with a factor combining ramming density and grain size. Such a factor can be obtained by the product of the Gittus number A_c of a sand and the ramming density ρ_2. Figure 3-3 shows the suggested correlation. The obvious limitation of such a correlation has been outlined in the previous paragraphs, i.e., the suggested change of conditions of contact with decreasing grain size of a sand. Nevertheless, it is interesting to note that 25 of the 29 points lie between or upon two lines drawn at an approximate deviation of 0.002 cgs units from the most favorable line.

Mold Chilling Power Effect on Casting Solidification Time

The agreement between the experimental and the predicted relationship of solidification time and volume-to-surface ratio appears to be quite reasonable, when one takes into account the assumptions made in applying the basic equations of the heat flow. It is interesting to note that when account is taken for heat losses through the gating system (using the method described in the Appendix to this section), the agreement for the castings made in the fine sand molds is improved (Fig. 3-10). It is also possible to correct for riser losses in the cases of medium and coarse-grain sand castings, but the corrected relation deviates only slightly from that originally predicted.

The results of the experiments made in green sand molds seem to indicate several important features which may be briefly summarized:

1) Moisture effect on the chilling power is clearly

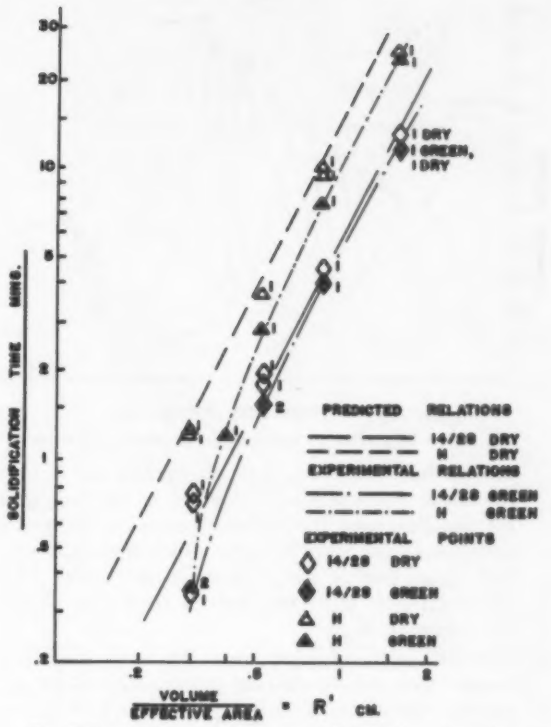

Fig. 3-5 — Moisture effect on solidification time for aluminum-bronze plates.

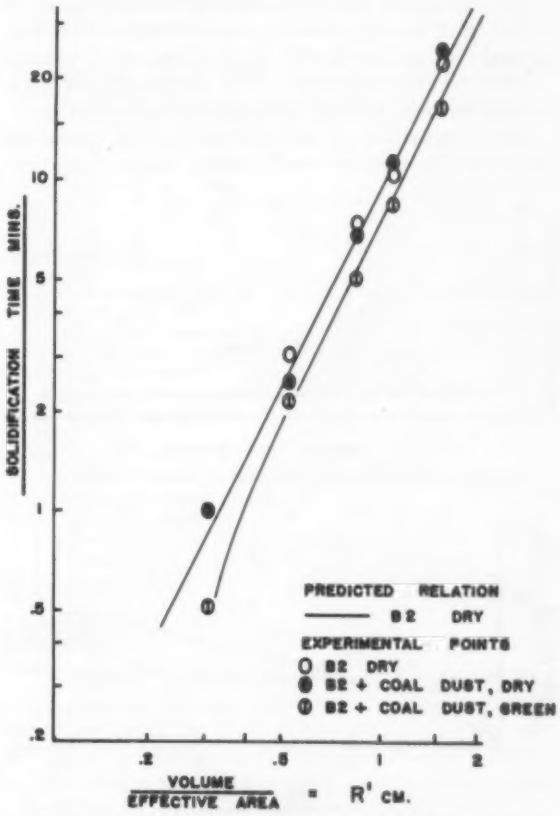

Fig. 3-6 — Coal dust effect on the chilling power of B2 sand for various plate sections in aluminum-bronze.

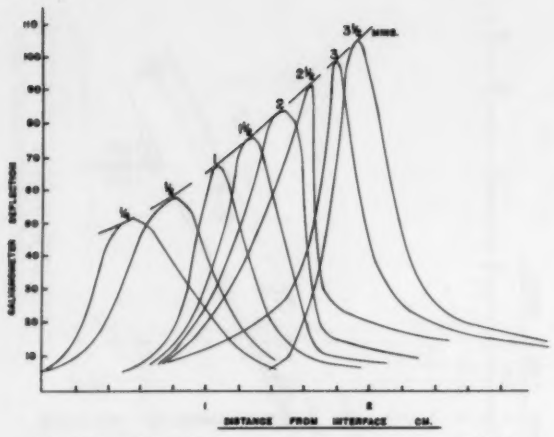

Fig. 3-7 — Migration of moisture in coarse sand 14/28.

shown, but the effect depends greatly on section thickness. Particularly interesting is the fact that for the fine sand the chilling power in the green state associated with the ¼-in. thick section, is several times that of the sand in its dry state. This chilling power is in fact greater than that of the dry coarse sand.

2) The coal dust addition to a dry sand has little or no effect on its chilling power. This is an apparent disagreement with previous work.[12] There appears to be a decrease in chilling power at larger casting thickness which is quite probably real, since the difference in solidification times of the three castings made in molds with and without coal dust is considerably larger than any deviation through experimental error (although the differences are reduced on a logarithmic plot).

The unusually high value of the chilling power of the green fine sand for small casting thickness as compared with the dry fine sand may be explained by means of the results of the moisture migration experiments (Fig. 3-7, 8 and 9). The movement of the peak moisture contents which may be considered as a prime mode of heat transfer in the time during and immediately after pouring, are shown in Fig. 3-9, being derived from the two previous figures. The figure would indicate a most sudden evaporation and outward movement of moisture in the fine sand during a period corresponding to the times of solidification of the ¼- and ⅜-in. thick castings, those casting thicknesses where the chilling power exhibited by the mold was greatest.

The fact that the curve then flattens out would also seem to correspond with the almost stationary value of chilling power for the greater casting thicknesses.

In the instance of the green coarse sand, the moisture movement is more gradual, corresponding to the gradual change of chilling power with casting thickness. Any explanation of why this change in chilling power differs for the two sands would undoubtedly involve the loss of moisture near the mold face on standing during the interval between molding and pouring (usually about 20-30 min). The drying-out of the fine sand during this period would probably be much less than that experienced in the coarse sand which has a much higher permeability.

The great increase in the height of the peaks

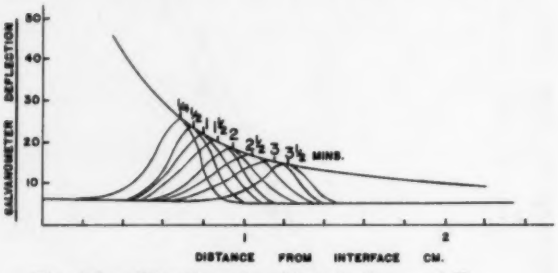

Fig. 3-8 — Migration of moisture in fine sand *H*.

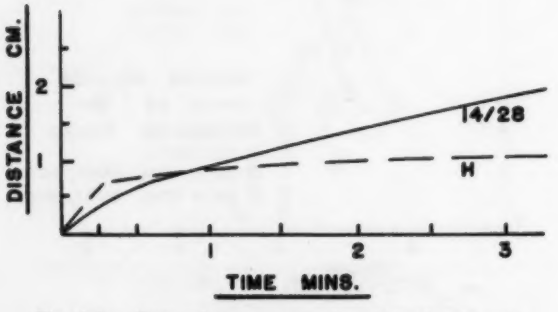

Fig. 3-9 — Rate of movement of peak moisture contents in the two sands studied.

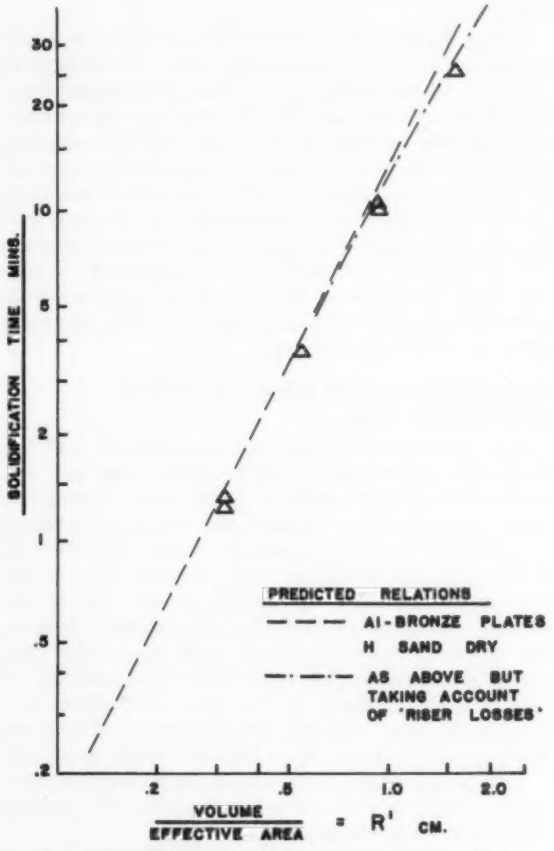
SOLIDIFICATION TIME MINS.
PREDICTED RELATIONS
Al-BRONZE PLATES
H SAND DRY
AS ABOVE BUT TAKING ACCOUNT OF 'RISER LOSSES'
VOLUME / EFFECTIVE AREA = R' CM.

Fig. 3-10 — Effect of taking account of riser losses into heat dissipation.

(Fig. 3-7) in this latter case might possibly indicate the pattern of the dried-out portion.

SUMMARY AND CONCLUSIONS

The following summarizes the findings of the present work:

1) Using a mold calorimetric method, the mean heat diffusivity, b_s of several molding sands in green and dry states and in several conditions of ramming have been calculated and graphed.
2) Theoretical relationships between b_s and ramming density ρ_s have been obtained, derived from the methods of Gittus and Russell. The agreement between these relationships, and the results obtained by the mold calorimetric method, are as good as the present state of the theory permits.
3) Using the values of b_s obtained by measurement, the prediction of solidification times of plates of various sizes in three types of molding sands has been carried out with a good measure of success.
4) A potential probe technique has resulted in a satisfactory explanation being advanced to account for the variation of chilling power b_s of green sand molds with casting section thickness.

APPENDIX — HEAT LOSS THROUGH GATING SYSTEM

The method used to obtain a first or second order approximation of the amount of heat lost through gates and risers of the casting made was briefly as follows. The temperature distribution along a thin cylinder attached to a large mass (solidifying at a time greater than any of the castings to be considered) was measured semi-continuously with apparatus described previously (Fig. 3-11). From Fig. 3-11 it is possible to obtain the temperature gradient through the intersection of the two bodies at various times; by means of a graphical integration a mean value of this gradient over the time concerned (for example: $\rho - 10$ min 98.4 C/cm.

If then such a mean value is inserted into the equation:

$$\frac{\partial Q_g}{\partial t_{x=0}} = k_l \left(\frac{\partial \theta}{\partial x}\right)_{x=0} \quad \text{in cm/sec/cm}^2,$$

the rate of heat loss may be obtained, provided a value of k_l (the mean thermal conductivity) is available. The arithmetic mean of k_l at room-temperature* and at the melting point† should be a fair approximation (0.15 cgs units).

Since a mean value of $\left(\frac{\delta \theta}{\delta X}\right)_{x=0}$ has been assumed for the range of times considered, we are justified in writing:

$$Q_{g_t} = k_l \left(\frac{\Delta \theta}{\Delta X}\right)_{x=0} \cdot t$$

This quantity may then be subtracted from the total heat of solidification for the casting on pouring as in equation (1c).

For the particular range 0 to 10 min with the ingate used:

$$\frac{\Delta Q_g}{\Delta t} = 30.5 \text{ cal/sec}$$

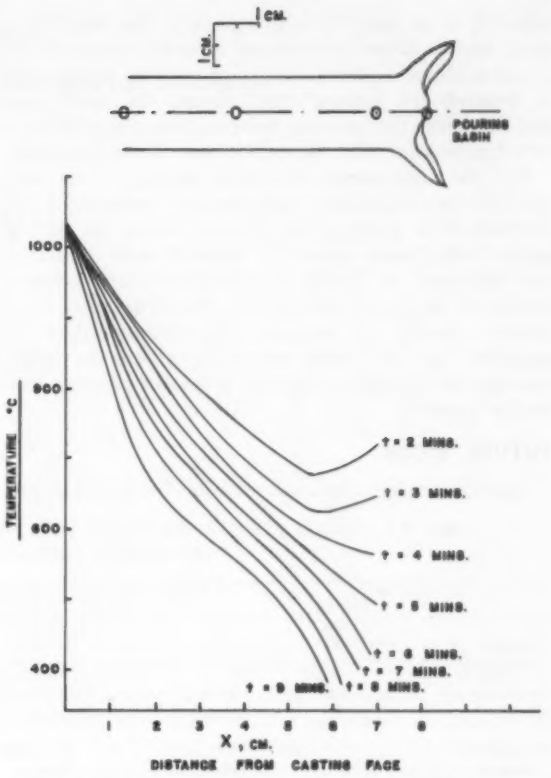

Fig. 3-11 — Temperature gradients developed in a narrow cylinder connecting a large casting with a pouring basin.

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SUMMARY

The present paper has shown how, within the limits of accuracy that are imposed by simplification of the theory, and the lack of totally suitable thermal constants, the solidification times t_s of simple shapes can be related to the effective volume-to-surface area ratio R' by means of the simple equation

$$t_s = M_{s,c,p} (R')^2$$

*A.S.M. *Metals Handbook*.

†R. Ruddle and A. Mincher, *Jnl. Inst. of Metals 78*, p. 229, 1950-51.

where t_s is in min, R' is in cm, M is the mold constant and S, C and P indicate separate values of M for each shape (spheres, cylinders, plates) considered. M depends on, among other things, the mold type and hardness, the pouring temperature, the solidification temperature and the latent heat of solidification.

For the convenience of those dealing with problems of risering, gating, pouring and progress of solidification in general, the exteme values of M, together with typical values for "sand-foundry" practice, are tabulated in Table 3-1 (The turbulent pouring condition is not considered for the Al-Si alloy since practice should not warrant this, although data are included for the other materials, where in larger castings the presence of partly turbulent pouring cannot be ignored).

FUTURE WORK

Apart from the application of the information presented in the present paper to such problems as feeding, control of casting stresses, knock-out time calculations and the correlation of solidification time with mechanical properties, much ground remains to be covered in the basic sphere of heat transfer. In particular, the interrelation of heat loss and degree of turbulence for various shapes gated in differing modes is worthy of considerable study. Finally extension of work concerning mold chilling power and properties of liquid metals to cover the fullest possible range of materials is required.

ACKNOWLEDGMENT

The authors are grateful to many people at the University of Birmingham, England, particularly Prof. A. J. Murphy and Prof. E. Rollason, for making financial support available. Also to Mr. John Gittus, the Mond Nickel Co., Ltd.; the Directors and Management of Tangyes, Ltd., particularly Mr. John Grice, for providing iron casting facilities; and to the staff of Armour Research Foundation, Chicago.

TABLE 3-1 — MOLD CONSTANTS UNDER VARIOUS CONDITIONS FOR ALUMINUM-SILICON EUCTECTIC, ALUMINUM BRONZE, CAST IRON AND STEEL

Alloy	Filling Temp.[a] C (F)	Mold Conditions: Green or Dry	Grain Size	Soft or Hard Rammed	Mold Constants[b]: M_s	M_c	M_p
Al–13% Si eutectic	690 (1274)	Dry	Medium	Medium	8.07	8.75	11.86
		Green	Medium	Medium	4.79	5.24	7.26
		Dry bonded magnesite (1.95 g/cc)[c]			1.05	1.15	1.60
Aluminum bronze eutectic	1240 (2644)	Dry[d]	Medium	Medium	7.18	7.84	11.31
		Dry[d]	Coarse	Hard	4.26	4.64	6.54
		Dry[e]	Fine	Soft	8.56	9.50	14.82
		Plaster sleeving (0.745 g/cc)			12.97	14.62	28.39
		Dry bonded magnesite (1.95 g/cc)[c]			1.89	2.05	2.83
	1180 (2156)	Dry[d]	Medium	Medium	6.04	6.58	9.24
		Dry[d]	Coarse	Hard	3.59	3.91	5.33
		Dry[e]	Fine	Soft	6.57	7.73	12.23
		Plaster sleeving (0.745 g/cc)			11.10	12.63	23.21
		Dry bonded magnesite (1.95 g/cc)[c]			1.72	1.70	2.31
Cast iron (eutectic carbon equiv.)	1290 (2354)	Dry[f]	Medium	Medium	6.66	7.27	10.36
		Dry[f]	Coarse	Hard	3.97	4.29	5.98
		Dry[g]	Fine	Soft	7.98	8.85	13.74
		Dry bonded magnesite (1.95 g/cc)[c]			1.75	1.86	2.58
	1200 (2192)	Dry[f]	Medium	Medium	4.13	4.45	6.09
		Dry[f]	Coarse	Hard	2.52	2.70	3.52
		Dry[g]	Fine	Soft	4.91	5.64	8.08
		Dry bonded magnesite (1.95 g/cc)[c]			1.11	1.18	1.52
0.1 - 0.2% C Steel	1585 (2885)	Dry/green	Coarse	Hard[h]	1.28	1.38	1.99
		Diatomaceous earth and sand[i]			9.22	10.47	19.11
	1485 (2705)	Dry/green	Coarse	Hard[h]	0.87	0.95	1.27
		Diatomaceous earth and sand[i]			6.48	7.27	12.16

a) Filling temperatures represent:
690 (1274) — most quiscently poured small shapes in Al-Si, P.T. 700-720 C (1292-1328 F).
1240 (2644) — most quiescently poured shallow shapes in Al bronze, P.T. 1250-1270 C (2282-2318 F); also, top-poured deep shapes (S and C), P.T. 1310-1330 C (2390-2426 F).
1180 (2156) — top-poured deep shapes in Al bronze, P.T. 1250-1270 C (2282-2318 F); also, most quiescently poured shallow shapes, P.T. 1190-1210 C (2174-2210 F).
1290 (2354) — most quiescently poured shallow shapes in cast iron, P.T. 1300-1320 C (2372-2408 F); also, top-poured deep shapes, P.T. 1390-1410 C (2516-2570 F).
1200 (2192) — most quiescently poured shallow shapes in cast iron, P.T. 1210 C (2210 F); also, top-poured deep shapes, P.T. 1300 C (2372 F).
1585 (2885) — most quiescently poured shallow shapes in low-C steel, P.T. ~1600 C (~2912 F); also, top-poured deep shapes, P.T. ~1700 C (~3092 F).
1485 (2705) — most quiescently poured shallow shapes in low-C steel, P.T. ~1500 C (~2732 F); also, top-poured deep shapes, P.T. ~1600 C (~2912 F).

b) $t_s = M_{S,C,P}(R')^2$; $M = t_s$ for $R' = 1$ cm. S = spheres, C = cylinders, P = plates.
c) See Ref. 3, Part 3.
d) Applies also to green molds over ~½ in. section.
e) Applies also to green molds over ~1 in. section.
f) Applies also to green molds over ~⅜ in. section.
g) Applies also to green molds over ~¾ in. section.
h) See Ref. 1, Part 1.
i) See Ref. 33, Part 1.

1959

Charles Edgar Hoyt Memorial Lecture

THE CONTROL OF QUALITY IN THE BRASS FOUNDRY

By Harry M. St. John

INTRODUCTION

It will be obvious to all that the subject of this lecture cannot be given exhaustive treatment in 30 or 40 minutes. One would have to include a detailed discussion of foundry practices, testing methods and an analysis of defects, any one of which would be more than sufficient to fill our allotted time. What I hope to do is to emphasize what might be called the philosophy of foundry control with such references to its technology as will cover useful procedures not commonly practised.

The control of quality in the brass foundry has two objectives, differing somewhat in purpose and in the methods employed.

First of all, the foundryman must guard against the delivery of unsatisfactory castings to his customers. If he fails in this, his reputation and, to some extent, the reputation of the whole foundry industry suffer.

Of no less importance, if the foundryman is to make a profit and continue in business, is the control of losses due to defective castings, particularly those which prove to be defective after machining or after assembly in a finished product. He must also realize that, if the percentage of rejected castings is large, many of those which pass all tests may be of substandard quality.

The captive foundry is fortunate in that it has a captive customer. Its castings are machined, assembled and tested in the plant which houses the foundry. Troubles can be quickly detected and corrective measures promptly taken. Partly for this reason, some jobbing foundries machine their own castings and give them a final test before delivery to customers.

SPECIFICATIONS

When castings are made to specification, such as are issued by A.S.T.M., S.A.E. and various departments of the Federal Government (Table), chemical composition and such physical properties as tensile strength and per cent elongation are emphasized. This information is of value to the customer as evidence that he is receiving what he has ordered; it is of little help to the foundryman except as it may indicate a trend in the quality of his metal. Even the customer must remember that there is no essential relationship between test-bar results and the quality of castings made from the same heat. A good test bar (Fig. 1) proves that the bar was well made from good metal. Castings from the same heat might be spoiled by any one of a number of faults, such as pouring at a wrong temperature. A poor test bar may be badly made from good metal.

Case History

A personal experience will serve to illustrate the point. The foundry was required to make a large number of manganese bronze valve stems of varying size. It was specified that test bars should have a minimum tensile of 60,000 psi, a minimum elongation of 18 per cent. But it was also specified that the maximum elongation should be 22 per cent, the explanation being that, in case of failure, the customer wanted the casting to break without too much stretch.

An unexpected difficulty was encountered. We

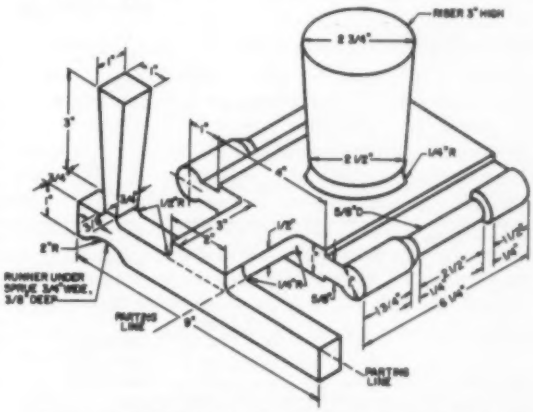

Fig. 1 — Double horizontal full-web type test bars (A.S.T.M. Designation B208-49T).

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TABLE — CONFORMING SPECIFICATIONS FOR COPPER-BASE ALLOYS

Class	Alloy	A.S.T.M.	Federal	Navy	Military	S.A.E.	A.M.S.
Tin Bronze	88-10-0-2	B143(1A) B30(1A)† B22-D				62	4845C
	88-8-0-4	B143(1B) B30(1B)†	691-5 701-5†	46M 6 46B25-III†	16576	620	
	85-15	B22-B	691-9 701-9†	46B22-III	16261		
	81-19	B22-A	691-10 701-10†				7322
	89-11					65	
Leaded Tin Bronze	88-6-2-4	B143(2A) B30(2A)† B61	691-1 701-1†	46B 8 46B25-I†	16541	622	
	87-8-1-4	B143(2B) B30(2B)†	691-6 701-6†	46B 5-I	16540	621	
	87-10-1-2						
	88-10-2-0					63	4846
	87-11-1-0-1					640	
High Lead Tin Bronze	80-10-10	B144(3A) B30(3A)† B22-C				64 792	4842 4827C
	83-7-7-3	B144(3B) B30(3B)†	691-12 701-12†	46B22-VI	16261	660	
	85-5-9-1	B144(3C) B30(3C)†				66	
	78-7-15	B144(3D) B30(3D)† B66	691-7 701-7†	46B22-IV	16261		4825A
	70-5-25	B144(3E) B30(3E)† B66-B67		46B22-V	16261		4840
	84-8-8		691-8 701-8†	46B22-II	16261		
	71-13-16		701-13†	46B22-VIII	16261		
	75-5-20	B66		46B22-I	16261	794	
	81-8-11	B66					
Leaded Red Brass	85-5-5-5	B145(4A) B30(4A)† B62	691-2 701-2†	46B23 46B25-II†	16444	40	4855A
	83-4-6-7	B145(4B) B30(4B)†		46B 5-III	16540		
Leaded Semi-Red Brass	81-3-7-9	B145(5A) B30(5A)†	691-4&11 701-4&11†	46B24 46B 5-III	16540		
	76-3-6-15	B145(5B) B30(5B)†					
	80-5-2-13		691-3 701-3†	46B21	16542		
Leaded Yellow Brass	71-1-3-25	B146(6A) B30(6A)†	621-C	46B11-II			
	67-1-3-29	B146(6B) B30(6B)†	621-B	46B11-I		41	
	63-1-1-35	B146(6C) B30(6C)†	621-A	46B10			
Manganese Bronze	60-20-15*	B147(7A) B30(7A)† B132-A	726-D 731-D†				
	65-25-20*	B147(8A) B30(8A)†	726-A 731-A†	49B 3 46B25-V†	16443	43	4860
	90-45-18*	B147(8B) B30(8B)†	726-B 731-B†	46B29-b 46B25-VII†	16522	430A	
	110-60-12*	B147(8C) B30(8C)†	726-C 731-C†	46B29-a 46B25-VI†	16522	430B	4862A
Aluminum Bronze	88-3-9	B148(9A) B30(9A)†	671-A 675-1†	46B18-1 46B19†‡	16033	68A	
	89-1-10	B148(9B) B30(9B)†	671-B 675-2†	46B18-2	16033	68B	
	(86-4-10 or (84-4-10-2	B148(9C) B30(9C)†	671-C 675-3†	46B18-3	16033		4870-71 4872-73
	79-5-11-5	B148(9D) B30(9D)†	671-D 675-4†	46B18-4	16033 6947		

(Continued on following page)

SPECIFICATIONS — Continued

Class	Alloy	A.S.T.M.	Federal	Navy	Military	S.A.E.	A.M.S.
Nickel Silver	12% Nickel	B149(10A) B30(10A)†					
	20% Nickel	B149(11A) B30(11A)†		46C12			
	25% Nickel	B149(11B) B30(11B)†					
Silicon Bronze	1-5% Si 5% Zn max.	B198(12A)	C-593	46B28-b			
Silicon Brass	2½-4% Si**	B198(13A)		46B28-a			
	3-5% Si**	B198(13B)		46B28-a			

*Mechanical properties of the manganese bronzes.
**12 to 16% zinc.
†Specifications are for ingot.
‡46B19 superseded by QQ-B-675-1.
ASTM—Year suffix not listed.
Federal—All specifications prefixed by QQ-B except QQ-C-593.
Navy—Small letter suffix not listed.
Military—All specifications prefixed by MIL-B except MIL-M-16576. These Specifications supersede Navy Specifications in column to the left.

couldn't get the elongation down to 22 per cent. Various things were tried, without success. For example, the addition of a little tin resulted in brittleness and an elongation far below 18 per cent. The customer agreed to accept a bronze of higher tensile and it was thought that in this way a lower elongation could easily be attained. To our amazement we made test bars having a tensile of 100,000 psi and 30 per cent elongation. The customer's inspectors were very helpful. They suggested that test bars be machined from castings, selecting for the purpose castings which would otherwise have been scrapped. This solved the problem.

The matter of chemical composition has two differing aspects. First of all, if a specification is to be met, the principal elements in the alloy must fall within the prescribed limits. Chemical analyses take time. Usually they tell what happened day before yesterday, too late to be of immediate use to the foundryman. The spectroscope offers a rapid means of analysis which, in iron and steel foundries, can be used to correct composition while the metal is still in the furnace.

The ingot manufacturer makes good use of the spectroscope to measure the progress of refining in his large reverberatory furnaces. But in nonferrous foundries, where heats are small and frequent, it is not practical to wait 10 or 15 minutes while a spectroscopic analysis is being made. About the best the brass foundryman can do is to study the analyses as he receives them and from these determine what variations are likely to occur. He can then compensate by adding more zinc or by any other change which seems to be needed.

Specification Importance

The importance of chemical specifications varies with their interpretation. If a specification calls for a maximum of 86 per cent copper and a minimum of 4 per cent lead, castings containing 87 per cent copper and 3 per cent lead are likely to be rejected in spite of the fact that they may have superior properties. The foundryman should bear in mind that the control of quality means giving the customer what he asks for, not something better than he wants or needs.

Deviations of composition such as the one just mentioned are most likely to result from the mixing of alloys in the handling of gates and machine turnings. If this occurs it means that expensive metal is being downgraded into a less expensive alloy with a resulting increase in cost.

The second important aspect of chemical composition is the presence of impurities which may be detrimental or will at least influence the behavior of the metal in the foundry. This applies particularly to those alloys which are most sensitive to pouring temperature, the red brasses and tin bronzes. Here uniformity is the prime requisite. For example, iron up to a permissible maximum of 0.25 per cent probably has no specific bad effect on the metal, but if this is followed by another lot of ingot containing 0.05 per cent iron there may be as much as 50 F difference in pouring temperature. The foundryman would be saved trouble and loss if both lots of ingot analyzed 0.15 per cent iron. In these alloys nickel may be termed a desirable impurity but variations of this element within specification limits can produce wide swings in the best pouring temperature.

INSPECTION

Castings should be inspected before machining for surface quality and evident defects. They should be inspected again after machining for machine spoiled and foundry defects not previously apparent. This can very well be part of the assembly operation. If inspection is well done the percentage of castings which leak when given a pressure test will usually be small, in the neighborhood of one per cent. If the foundry machines its own castings it may pay to pressure test a small percentage of each lot after machining. Then, if an exceptional number of leakers is found in any lot, a 100 per cent test is advisable for that lot.

Dimensional accuracy has an important bearing on the cost of machining. There must always be enough stock so that the casting will "clean up" to conform

with the blueprint. Excess stock is a needless cost to both foundry and machine shop. Modern sand conditioning and molding practice make possible close dimensional tolerances. Sometimes it is even possible to eliminate a machine operation previously thought necessary.

Marked improvements have recently been made in green sand molding. For many years the American Foundrymen's Society has made an intensive study of sand properties and sand conditioning. While brass foundries were a little slow to take advantage of the information thus made available, most foundries now employ sand testing equipment and do a reasonably good job with it. Much less attention was paid to the making of molds until the advent of shell molding, a process which makes possible the attainment of closer tolerances than previously found in brass foundry practice. While some brass castings are being made by the shell process, the principal impact of shell molding in the brass foundry has been to stimulate improvements in green sand molding.

It has been learned that the use of higher pressures and stronger sands result in finishes as fine and tolerances as close as can be obtained by any other method except the "lost wax" process. Where a mold hardness of 75 was formerly the usual thing and is still commonly found, most advanced practice calls for a hardness of 90 to 95. For larger castings the diaphragm method has been a factor in the improvement.

To obtain closer tolerances it is also necessary to make patterns more closely to prescribed dimensions. Allowing "plenty of finish" so that surface defects could be machined away was never good practice, is now less acceptable than ever.

SCRAP STUDY

There is no such thing as perfection in any manufacturing operation. The foundry is no exception. Competent testing and inspection will always find rejects but these must be held to a minimum if the foundry is to maintain a competitive position with other foundries and with other methods of forming metal parts. In the making of small castings, where a considerable number of molds is to be poured from one crucible or ladle, an overall loss of 5 per cent of the gross casting weight is a reasonable goal which should at least be approached. Failure to do so can easily mean an excess cost of several cents per pound of finished castings.

At this point it may be well to mention a fallacy which still lingers in some foundries. In these it is believed that tests and records are a waste of time and money, that a good foundryman, by the exercise of intelligence and experience, will produce a maximum of good castings, a minimum of rejects. Nothing could be further from the truth. Tests and records are among the foundryman's most important tools. To make best use of them requires the full employment of his skill and experience. Without them he suffers a severe handicap. I have in mind two instances where the study and recording of scrap greatly reduced scrap losses without any change in foundry personnel. In one case losses were reduced from 16 to 6 per cent, in the other from 12 to 3 per cent. Similar cases are numerous.

Troubles which are responsible for unsatisfactory quality may for convenience be divided into six classes:

1) Surface blemishes, which, while they may not interfere with the function of the casting, do spoil its appearance.
2) Misshapen castings not only give a poor appearance but often cannot be machined to the dimensions desired for the finished casting.
3) Castings in which the metal does not completely fill the mold cavity.
4) Castings which have internal shrinkage cavities resulting in lack of strength and pressure tightness.
5) Nonmetallic inclusions embedded in the casting.
6) Castings of substandard structure due to gas porosity or granular coarseness.

There are several definite points where foundry operations should be tested and controlled in order to keep casting defects at a minimum. These are concerned with the quality of the metal, the molding sand and cores and with the mechanics of making and pouring molds.

METAL QUALITY

It is first of all essential to ensure that the quality of metal, as it goes to the melting furnaces, is good. Watchful care should be used to make sure that foundry returns are clean and dry. A little molding sand on gates and sprues does not seem to matter greatly but should not be excessive. Scrap castings should be free from grease and broken tools. Machine turnings should be free from tramp iron and organic substances and must be dry, without oil and cutting compounds. Metal spillings and skimmings should preferably have been cleaned by a concentrating operation and then dried. The importance of not mixing alloys of differing composition has already been mentioned.

Most brass foundries use composition ingot in quantity sufficient to make up the weight castings shipped plus metal losses. While the chemical composition of ingot should not be neglected it is not the only factor which determines ingot quality.

When ingot is purchased in large lots performance tests are sometimes made. Sample castings may be made and fractured. Test bar results are useful. One procedure which may occasionally be worthwhile is to make a series of test blocks, poured at intervals from 2300 F down to about 2050 F. The specific gravity and Brinell hardness of these blocks is then measured. Taking the red brasses and tin bronzes as examples, a specific gravity of 8.9 is as near perfection as one is likely to get. Anything above 8.6 is acceptable; lower values indicate objectionable porosity. If a specific gravity of 8.6 or better is obtained over a temperature range of 150 F the metal is of satisfactory quality.

Interpretation of Brinell readings will vary according to the composition of the alloy and can only be standardized by experience. Exceptionally low read-

ings indicate porosity, high readings brittleness. Deviations from normal in metal which has a good conventional analysis are not uncommon. The reasons for such deviations are a matter of speculation rather than definite knowledge.

A number of other methods for judging ingot quality have been suggested. In the deep etch test a cross section of the ingot is obtained by sawing and the section surface etched by acid. In my opinion the results of this test are not particularly enlightening. In the making of ingot there is no point in trying to obtain a dense, fine-grained structure and the most efficient methods of production are not such as to promote such a structure.

The presence of coarse dendritic crystals in the interior of the ingot is not evidence of inferior quality. Even a gassy ingot does not necessarily produce gassy castings, although it is better to specify that the top of the ingot should show shrinkage. Ingot with puffy tops should be avoided.

The relative merits of rough-top and smooth-top ingot are a matter of controversy. The argument in favor of the smooth-top ingot is that oxides and nonmetallics which might later cause trouble have been skimmed away. In favor of the rough-top it is said that the roughness is mostly copper oxide, a substance which, as a useful ingredient during the melting operation, is often added in the furnace. As a matter of personal experience, I have never been able to decide that there is any real difference in the results obtained with one or the other.

Fuel vs. Electric Furnace

Metal quality can be greatly impaired during melting. The precautions to be observed depend upon the type of furnace in use. With fuel-fired furnaces a slightly oxidizing atmosphere must be maintained but excessive oxidation is to be avoided. In electric furnaces, where a neutral atmosphere is desirable, reducing conditions due to the presence of finely divided carbon must be guarded against. In any furnace type, the presence of water vapor, whether from the metal charge or the furnace lining, can be very damaging.

Fluxes should be used sparingly and for a definite purpose, not as a matter of habit. In theory the best metal is that which is slightly oxidized during melting, then deoxidized before pouring (Fig. 2). In fuel-fired furnaces a slight degree of oxidation is attainable by control of the combustion gases. In electric furnaces, which normally have a stagnant neutral atmosphere, it is sometimes advantageous to use a mildly oxidizing agent such as manganese dioxide, copper oxide or the sulphates of barium or sodium. Their use is called for only when the metal has been exposed to a reducing condition such as the presence of oil, carbon dust or water vapor. All of these fluxes tend to shorten the furnace lining life.

The introduction of air for oxidizing purposes in electric furnaces is not recommended. Fluxes of the type mentioned are also sometimes employed in crucible furnaces. The use of borax in crucible furnaces helps to keep the crucible clean and to accumulate the dross and slag so that they can more readily be skimmed from the metal. Regardless of the type of melting employed the metal should be deoxidized before pouring by about 2 oz of phosphor copper per 100 lb of metal and thoroughly stirred prior to skimming.

As a matter of routine, melting practice can best be judged by examination of castings but, when trouble is encountered, important information can be gained by pouring test blocks which are then subjected to tests for specific gravity, Brinell hardness and fracture.

TEMPERATURE CONTROL

Although the importance of temperature control has been emphasized for many years and almost every brass foundry owns a pyrometer, practice in this respect often falls far short of what it should be. If a single large casting is to be poured, the foundryman usually has considerable leeway. Precise temperature control is of secondary importance as compared with the size and location of gates, risers, chills and insulating pads.

As a rule, however, the brass foundry's principal production consists of small castings, where the objectives are the largest possible number of castings in each mold and the largest possible number of molds poured from each crucible or ladle. Here temperature control is of prime importance.

Under average conditions we may assume that a well-designed, well-gated red brass casting has a temperature pouring range of 150 F. Molds poured at either higher or lower temperatures will produce excessive scrap. Poor gating or design will reduce the range as will substandard metal. During pouring the metal will cool at a rate of 0.8 to 1.0 F per second, depending upon the insulating quality of the crucible or ladle. The time required for pouring will vary from 8 to 10 seconds per mold. It appears then that we can pour only some 15 molds, or possibly 17 or 18 under most favorable conditions, and still keep within the pouring range of the individual casting. Roughly speaking, 10 F is equivalent to one mold and, if we could, we would like to measure the temperature that closely. The best pyrometers available are not

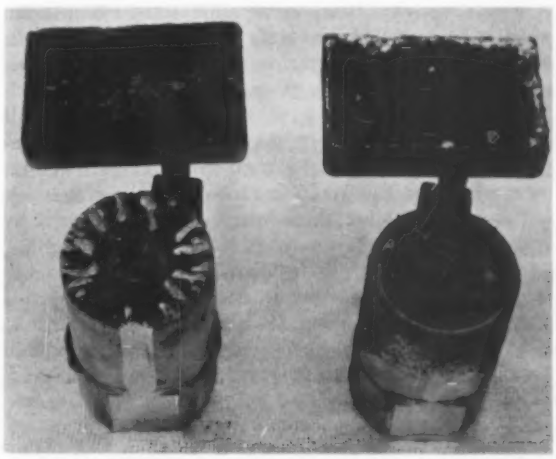

Fig. 2 — The riser on the left was from a heat that was not deoxidized. That on the right was deoxidized. Both were blind risers without vents.

ROUGH CASTING SCRAP						DATE 6-12-56
ITEM	PATTERN NO.	MOLDER NO.	DEFECTIVE NUMBER	DEFECTIVE WEIGHT	CODE NO.	REMARKS
1 1/2" BOZ	1012	12	50		1	
CENTERPIECE			42		2	
			36		5	
TOTAL			128	116		

Fig. 3 — Example of typical daily scrap report.

1½" BOX CENTERPIECE PATTERN 1012			FILE RECORD																
DATE	MOLDER NO.	CSTGS. MADE	GROSS CSTGS.	%C.R. SCRAP	%SHOP SCRAP	TOTAL % SCRAP	DEFECTIVES 1	2	5	6	14	18	20	ZZ	M	TOTAL
JUNE 56	12	2016	1998	24.5	10.3	34.8	200	153	138	18	106	50	50		34	698
JULY 56	12	1600	1590	8.2	2.8	11.0	20	12	6	15	20	13	12	20	10	128

Fig. 4 — File record form is permanent record of individual items produced.

quite that accurate although they can be read to 10 F.

SCRAP RECORDS

If we are to keep scrap at a minimum, then, the following conditions must be observed:

1) The quality of the metal must be good.
2) The design of the casting must be good.
3) The casting must be well gated.
4) The pouring temperature range must be known.
5) The pouring temperature must be closely measured and kept within the known range.
6) We must not pour any more molds from one ladle than variations in the above requirements permit.

Perhaps the most difficult problem is to determine the pouring range. This is a matter of trial and error, based on experience and good judgment. Each casting is an individual problem, to be solved by a study of the casting and its arrangement on the pattern plate. Incidentally, this arrangement and the gating are a job for the foundryman rather than for the patternmaker. Once decided upon, the pouring range should be recorded and the record consulted whenever the casting is made. It is obvious that detailed scrap records are here an essential tool.

Before we can have worthwhile scrap records we must have a skilled diagnosis of scrap, made by men who understand the various scrap causes and can identify each for what it is. One procedure which has worked well is to have the sorter throw out all castings which definitely are, or may possibly be, rejects. This accumulation is then inspected by a skilled man who lists the scrap castings according to their faults and sets aside those which can be salvaged by corrective work.

The scrap sorter's figures are combined and tabulated so that each casting item has in the file a card showing its performance. Its history over a period of time provides a basis for decision when a change in gating or pouring temperature is to be considered. Figure 3 illustrates a card on which scrap data are collected; Fig. 4 a permanent record.*

*Figures 3 and 4 are reproduced from *Brass and Bronze Foundry Practice* by H. M. St. John. Courtesy of Penton Publishing Co.

While the collection and study of scrap information constitute an important procedure for scrap control the results are too slow to catch troubles as they occur. For this purpose nothing so far available equals facture tests. The systematic test, developed under the auspices of the AFS Brass & Bronze Division's Research Committee, is useful although its interpretation is somewhat difficult. It principal contribution has been to our basic knowledge.

In the average brass foundry nothing has taken the place of fractured castings, examined in the light of long experience. The color and structure of a freshly fractured casting are difficult to describe for interpretation by a novice but to the veteran they tell a story he can get in no other way. The location of the fracture is important as is the manner in which it is made. A crushing machine is a useful adjunct to the foundry's equipment. Lacking this, hammer and vise will serve.

MOLDS AND MOLDING

Molding sand and the manner in which molds are made are important factors in their effect on casting quality. Up to the date of its publication, the AFS FOUNDRY SAND HANDBOOK covers the matter thoroughly but there have been many recent developments which can only be found in current literature. The present trend in green sand molding is toward harder molds which yield castings of closer dimensional tolerances. The frequent use of a mold hardness tester is indispensable. Whether or not facing sand is used, the properties of that portion of the sand which comes in contact with the pattern must be carefully controlled and periodically tested. One of the most important requirements is to keep this sand free from clay balls and from fragments of metal.

For thousands of years makers of castings used molding sand as they found it in nature. Now this practice is changing, for two reasons. First, natural supplies of suitable sand, with the right proportions of desired grain size and shape, blended with the needed amount of the right kind of clay, are becoming scarce. Next, it has been learned that nature's sands can be improved by blending with each other and with additional elements. The highest standards of quality now prevailing can hardly be achieved in any other way.

Brass and bronze require fine-grained sands. For a first class finish on small castings the base sand should have an AFS fineness of 150 with closely grouped screen size. In practice a certain amount of coarser core sand becomes mixed with the molding sand, thus decreasing the fineness number of the sand in use to a possible 130. The sand grains should preferably be rounded since the tendency of sharp sand to pack makes permeability control difficult. If all grains were perfectly round and of the same size, regardless of what that size might be, the percentage of voids between the grains would be 33⅓ per cent. The more closely the sand is grouped in a few adjacent screen sizes the more nearly we approach this condition.

Finer sands will still have a somewhat lower permeability because of the more tortuous path gasses

must follow in passing through the sand. Any excess of clay or other bonding material will tend to fill the voids and reduce permeability. The addition of a finer sand will also tend to fill voids and decrease permeability but the addition of a coarse sand will not increase permeability unless the addition is so great as to make the coarse sand dominant.

The so-called synthetic sands have many advantages. They permit a control of molding sand properties more complete than is otherwise possible. For this is required a sand almost if not quite free from clay to which a measured quantity of a selected bond and such other substances as may be desired are added. This has become common practice in iron and steel foundries for whose purpose suitable sands are readily available. Some of these sands work very well for the high-nickel nonferrous alloys and even for brass and bronze castings when these are large, say 100 lb or more. With a well-grouped AFS fineness of 100 to 110, a clay content of one or two per cent, a satisfactory finish can be obtained on these and also on manganese bronze.

But for small brass castings sufficiently fine sands with a low clay content are scarce and costly. A few are available having an AFS fineness of about 150 and a clay content of 5 or 6 per cent. These can be used to good advantage adding bentonite as the principal bond. Crushed sandstone, screened to the required size, is also a possibility.

The brass foundryman has one other recourse which, in many cases, is his best bet. He can take a fine sand which is too rich in clay and blend it with used sand which has been passed through a fine screen to remove metal particles. Foundry floor sweepings and sand which has been spilled from poured molds are suitable for this purpose. They will be low in bond and sufficiently dry, two per cent moisture or less, for fine screening. Heap sand which has been dried to this point may also be used.

Facing Sand Use

To an increasing degree the brass foundryman is finding that he can most effectively get the results he wants by using facing sand of such a mixture as described above. This is much more practical than to process the entire bulk of his molding sand, most of which will simply serve as backing and need not have such specialized properties.

For best results a naturally bonded sand should have a permeability of 15 to 20, compressive strength of 6 to 8, tempered to about 6 per cent moisture. A good synthetic sand will show a permeability of 25 to 30, a strength of 10 to 12, moisture content of 4 per cent or less. In either case about one per cent of flour, either cereal or wood, should be added to give the sand elasticity. Other additives, such as soda ash and ethylene glycol, show promise but are still in the development stage. The same may be said of sand tempered with oil or synthetic plastics in place of water. Molding pressure is important. For squeeze or jolt-squeeze machines, the air pressure at the machine should be at least 100 psi.

Care of core quality is a matter which is too often neglected. The foundryman will do well to read Dietert's AFS classic* on this subject but again there are new developments in recent foundry literature. While 100 per cent inspection of cores is seldom advisable, a partial inspection is well worth while, followed in cases of trouble by complete inspection. It is cheaper to throw away cores than it is to throw away castings.

CORE TROUBLES

Core troubles are usually due to two causes, either too porous a surface resulting in "burn-in," or excessive gas causing blows in the casting. Baking time and temperature are critical and must be adjusted to suit the size of cores as well as the character of binder used. Where high permeability is essential a coating may be needed to yield desired smoothness of finish. As another possible source of gas, coatings should be avoided except when absolutely necessary. Thorough baking without the use of too high a temperature and careful drying of cores which have been pasted or coated will help to avoid many of the troubles commonly experienced.

Cores should be used as soon as possible after making to avoid moisture pickup. Since it is convenient to have molds ready to pour at the beginning of the day's work, completed molds from the previous day are often allowed to stand overnight. One hesitates to condemn this practice but it does involve danger of moisture pickup from the molding sand. Certainly unpoured molds should not stand over a holiday or weekend.

Without going into detail it should be added that the likelihood of core trouble is lessened by dielectric baking or by the use of shell cores or carbon dioxide cores. While these methods have drawbacks peculiar to themselves, they are finding increasing use and, in the course of time, may substantially change coreroom practices.

STATISTICAL QUALITY CONTROL

How often should tests be made and how complete should be the inspection? First of all let us say that, so far as possible, no bad castings should ever be allowed to reach the customer. At intermediate stages too much testing may result in a waste of time and money. Statistical quality control, its application in the foundry described in a recent AFS publication, Statistical Quality Control for Foundries, points the way toward avoiding this. With respect to any foundry operation it is possible to determine the operation's quality potential. That is to say, how much deviation from a fixed standard is to be expected and can hardly be avoided.

If the test of a sample shows a greater deviation, whether in properties or in number of rejects, then we can assume that there is a definite cause for this excess, something which can be found and corrected. While the mathematics involved are somewhat difficult, the principles governing the needed size of sample and number of tests can readily be understood. Statistical quality control is not generally practiced in the brass foundry but its study will be of benefit to any foundryman.

*H. W. Dietert, Modern Core Practices and Theories, American Foundrymen's Society, Des Plaines, Ill.

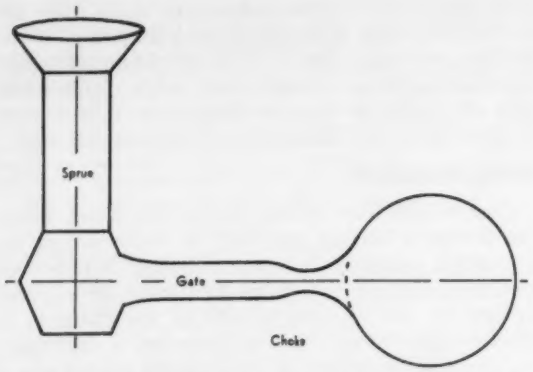

Fig. 5 — Choke gates are in general undesirable since they cause turbulence in the casting cavity and, except for light castings of uniform section, are likely to cut off the feed before the casting is entirely solid. As often used, choke gates are a prevalent cause of scrap. A choke at the bottom of the sprue is preferred.

GATING

The gating of red brass and bronze castings continues to be an art rather than a science (Fig. 5). Scientific progress has been made in the study of mathematical principles involved in the gating of metals such as steel and aluminum which have short freezing ranges, but the formulas derived for these metals are seldom of much use in the brass foundry where long freezing ranges are the rule.

The shrinkage characteristics of the red metals are such that small castings do not ordinarily require risers. On the other hand, the critical distances through which metal will feed from a gate are short so that multiple gating is commonly necessary. In determining the best practical gating one must consider the design of the casting, the arrangement of the castings on the pattern plate and the pouring temperature range which can be used without causing excessive scrap.

In most cases it is advisable to set up a new job with temporary gating designed according to the foundryman's best judgment, with the expectation that at least minor changes will have to be made after trial of the temporary gating. During this stage the pouring temperature should also be given careful study. Once established, the gating should not be changed without positive evidence of necessity. If there appears to be such evidence it should be examined carefully because of the likelihood that metal quality or pouring temperature, rather than gating, is at fault.

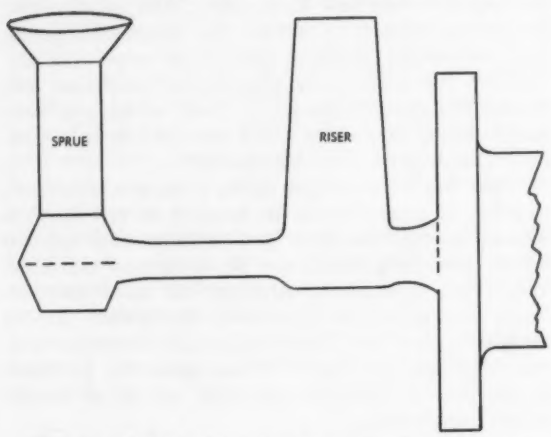

Fig. 6 — Method of locating riser to receive the last and hence the hottest metal, thus insuring adequate feeding.

The foundryman is under pressure to produce the highest possible casting yield, that is, the largest number of castings which can be made from each 100 lbs of metal melted. As a means to this end, nonproductive metal, in the form of gates, risers and sprues, should be reduced to a minimum (Fig. 6). Obviously if one goes too far in this direction excessive scrap will result and the yield of good castings will actually decrease.

The foundryman has a natural tendency to play it safe by making sure that there is plenty of metal. The closer one arrives at the highest possible yield the more necessary it becomes to maintain high metal quality and to exercise precise control over pouring temperatures, since both of these influence the adequacy of casting feeding.

Multiple Gating

Where multiple gating is employed the application of directional solidification becomes complicated and cannot readily be expressed in mathematical terms. It is commonly stated that the cross section of the gate should be 1½ times the casting section which it feeds, but with multiple gates it sometimes happens that one of the gates should have a cross section *smaller* than that of the casting. Where risers are used one finds recommendations for height ranging from 2½ to 1½ times the riser diameter, with approximately 25 per cent of the volume available for feeding purposes.

If insulating sleeves or exothermic compounds are used, the height must remain the same but available volume increases and diameter decreases. One must also remember that a blind riser is less effective than one open to the atmosphere and that the most effective riser of all is one placed between the sprue and the casting. All of which means that the foundryman must use his own judgment and profit by experience.

In most brass-foundry work castings are so small that several can be made in one mold, sometimes a large number. The problem then is to design runner and gates so that all are properly fed. The pattern maker is inclined to exercise his ingenuity in an effort to get the largest possible number of castings into the mold but in so doing he may defeat his own end since, after all, the objective is to get the largest possible number of *good castings.*

If the added castings turn out to be scrap, there has been a loss rather than a gain. Here the foundryman's know-how should be brought into play. He, in his turn, should endeavor to include as many castings as can be satisfactorily fed. Sometimes the possible saving is such as to justify a small increase in scrap.

CASTING DESIGN

The foundryman is not a casting designer and the casting designer is not a foundryman. Co-operation between the two is essential if problems which are

sometimes almost insuperable are to be avoided. The designer usually has in mind machine shop requirements and tries to design the casting in such a way as to make machining as convenient and inexpensive as possible. In doing so he may unwittingly greatly increase foundry costs. Or, in order to decrease the weight of the casting, he may saddle the foundryman with difficulties far more costly than the saving. This is particularly true of brass castings because brass is expensive and the designer does not want to be accused of "giving away" metal.

A complicated casting may offer a real problem to both designer and foundryman but simple castings are often at fault in this respect. Let us take the case of a valve body. Here, in Fig. 7, we have a casting which is almost impossible for the foundry to make. The seat section *S* is $\frac{5}{32}$-in. thick, while metal is saved at *C*, *D* and *E* by reducing the section to $\frac{3}{32}$-in. There is now no way of feeding the seat section. By thickening the section at *C* and *D*, at the *parting line only*, the seat section can be fed without greatly increasing the weight of the casting. This is equivalent to incorporating feeding gates in the body of the casting itself. The foundryman encounters many instances where solutions as simple as this can be found if the designer can be induced to consult him.

Foundryman and Designer

The foundryman can be of help to the designer in a number of ways, including the quality of the casting as well as the cost of making it. His familiarity with the nature of castings and with the properties of the metal he is using will enable him to point out what are likely to be weak spots and suggest means for their elimination. Among the fundamentals are the use of ample fillets at corners and the avoidance of an abrupt change from a thin to a thick section.

Differences in metal properties must be taken into consideration. Familiarity with iron, steel or aluminum may mislead the engineer when he designs for brass or bronze. When the same item is to be made in more than one metal it is frequently necessary to accommodate the design of the casting to fit the differing properties of the metals, either by changing the design or by making the design such that a sound casting can be poured from any of the desired metals. The latter practice is usually more economical than to have a number of different designs and patterns.

The engineer will read in his handbook that $\frac{3}{32}$-in. is the minimum workable thickness for the red alloys, $\frac{1}{8}$-in. for those higher in zinc, but he must remember that these minimum thicknesses are good only for short distances. Where there is to be a considerable area of thin section, these minimums must

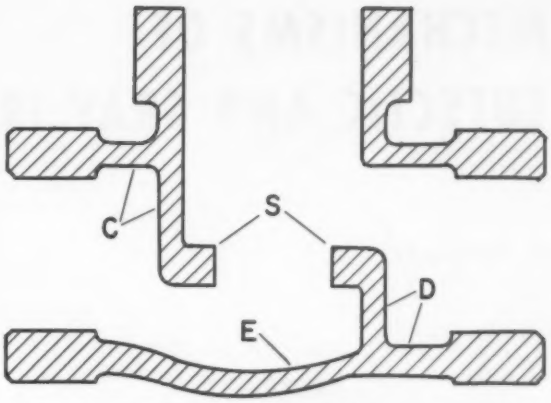

Fig. 7 — Sketch of valve body casting.

be substantially increased. Otherwise the pouring temperature range of the casting is cut down to a point where sound castings cannot economically be made.

The designer must also take an interest in gating since he must make sure that all parts of his casting can be fed with gates which can be fitted into a good pattern layout. For this reason there is some advantage in making a preliminary pattern layout before the design is made final in all details. It may be found that slight changes in design will make possible a better layout. When the casting is to be made in large volume a substantial saving is possible.

SUMMARY

To summarize, the foundryman needs to observe the following control points if he is to profitably serve a satisfied customer:

1) The quality and condition of metal going to the furnaces.
2) The quality and condition of molten metal from the furnaces.
3) The quality and condition of molding sand and molds.
4) The suitability of cores.
5) The soundness and condition of rough castings delivered to the machine shop.
6) The soundness and accuracy of castings delivered to the customer.

In support of this program, the foundryman should play a decisive part in the gating and pattern layout of his castings and act in an advisory capacity with respect to design.

Following such a schedule will cost something in both time and money but will yield returns out of all proportion to the cost.

SOLIDIFICATION MECHANISMS OF EUTECTIC AND GRAY IRON

By Albert De Sy

ABSTRACT

Any metallurgical transformation whose initial and final states are known but whose mechanisms are not established is a phenomenon not under control. Under these conditions, systematic processing to obtain a predetermined result is not possible. Observation does sometimes permit the establishment of correlations between processing variables and their influence on the result. But as long as the mechanism of the transformation is not known precisely, any intervention will be arbitrary, and full possibilities of control will not be realized. When the mechanism is known, the desired result can be obtained with a minimum expenditure of time and effort.

INTRODUCTION

The mechanisms of metallurgical transformations are generally difficult to determine since the transformations mostly occur at high temperatures and on a small scale. It is claimed in some quarters that these problems are of only theoretical interest; however, experience has shown that research into these transformations has resulted in the discovery and improvement of industrial procedures. This research always will be of assistance although it may not pay off for a considerable period, and for this reason enough basic research is not being conducted. For example, some purely basic research conducted at the Belgian Center for Foundry Studies and Research on the mechanism of the graphitization of gray iron[1] has produced results with important industrial applications. These findings have been recently confirmed.[2]

For the next two years, the Belgian Center for Foundry Studies and Research intends to undertake the study of the mechanism of gray iron solidification. This is a fundamental problem of gray iron metallurgy and appears to be well chosen. A study of the solidification of gray iron must consider the following items:

1) Initial or liquid state.
2) Actual solidification when both liquid and solid states coexist.
3) Final solid state existing immediately after solidification.

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The observation of the final state is hardly possible since we only see the structure at ambient temperature after it has been profoundly modified by cooling from the solidification temperature.

The liquid state or solution just above the melting temperature is a condition that is not perfectly understood. This liquid solution is called homogeneous. However, it is necessary to consider the degree of observation and the size of the sample which is termed homogeneous. A pure metal near the point of solidification contains pre-groupings, which are temporary associations caused by the chance movement of atoms or because of affinities between the atoms present in the liquid solution.

When the ternary Fe-C-Si system is considered, attractions between these elements produce a domain such that the Fe-C and Fe-Si pre-groupings predominate at the solidification temperature. It is probable that the latter destroy the former as the silicon content increases. The silicon, by attaching itself to the iron, liberates carbon, thereby increasing the activity of this latter element. This may probably explain the graphitization action of silicon in gray iron.

Solidification is a phenomenon of nucleation and growth. Nucleation is the predominating factor and deserves particular study. Nucleation can occur spontaneously or in a homogeneous manner, although this requires considerable undercooling. Nucleation can also occur from foreign nuclei, called heterogeneous solidification. The latter mode is the usual case, since undercooling values of 0.14 to 0.18 T_s (where T_s is the temperature of solidification expressed in °K) have been observed for homogeneous solidification. It is well known that the undercooling becomes more pronounced the greater the purity of the metal.

HOMOGENEOUS NUCLEATION

Homogeneous nucleation is the formation of a stable nucleus of the solidifying phase, by the assembly of a certain number of atoms of that phase in their crystallographic lattice. This nucleus is effective when it is capable of growing into a crystal. According to Volmer,[3] the effectiveness of a nucleus depends on its dimensions. Considering the solidification of a very small particle, the change in free energy may be expressed:

$$-\Delta F = -\Delta F_v + \sigma S \qquad (1)$$

where:

$-\Delta F$ = change in free energy of the system.
$-\Delta F_v$ = change in free energy resulting from the solidification of this elementary particle (change from liquid to solid state).
σ = surface energy per unit area at the liquid-solid interface.
S = surface area of the solid particle.

It is noted that ΔF_v and σS have opposite signs, since the latter term represents an increase in energy.

When the resulting $-\Delta F$ produces a decrease in free energy, the reaction or the solidification is spontaneous and will proceed. Solidification will not occur, however, when the resulting ΔF is positive.

Considering a particular shape of an elementary particle, for example a sphere, equation (1) may be developed in terms of the radius of the sphere. Assuming that the term ΔF_v is for a unit volume, then for a spherical particle of radius, r:

$$-\Delta F = \frac{-4\pi}{3} r^3 \Delta F_v + 4\pi r^2 \sigma \qquad (2)$$

ΔF_v and σ may be considered constant for a given metal at a given temperature and

$$-\Delta F = f(r)$$

where:

$-\Delta F$ is the algebraic sum of the two terms.

This function is represented graphically in Fig. 1. The function goes through a maximum whose value in terms of the variable r may be found by setting the first derivative equal to zero. Accordingly:

$$r = r_c = \frac{2\sigma}{\Delta F_v} \qquad (3)$$

The value r_c is called the critical radius. The interpretation of the facts in Fig. 1 may be summarized as follows.

Atom Movement

The chance movement of atoms in the liquid metal at or below the liquid-solid equilibrium temperature produces agglomerations of certain numbers of atoms. These agglomerations form at various locations in the melt, but are unstable at first since they form, disappear and re-form elsewhere. Considering an agglomeration of a volume equivalent to a sphere of radius $r<r_c$, the embryo may (depending on the chance movement of atoms in its vicinity) increase in size or may redissolve. Since the curve for $-\Delta F$ vs. r (Fig. 1) shows that any increase in r, when $r<r_c$, results in an increase in free energy, the chance that the agglomeration (embryo) will grow and attain the dimensions of a stable nucleus are practically nonexistent.

However, if the embryo resulting from the chance movement of atoms in the liquid phase is formed with dimensions equivalent to a sphere of radius $r>r_c$, any increase in radius corresponds to a decrease in free energy of the system and the nucleus will probably grow. The chance of continued growth increases as the radius r_s is approached. For this reason, r_c at the maximum point of the curve is called the critical radius. A nucleus which has attained or surpassed the dimension r_s is an absolutely stable or effective nucleus, and will practically always grow to a crystal. Homogeneous nucleation occurs with great difficulty, and only happens when undercooling has become sufficiently pronounced.

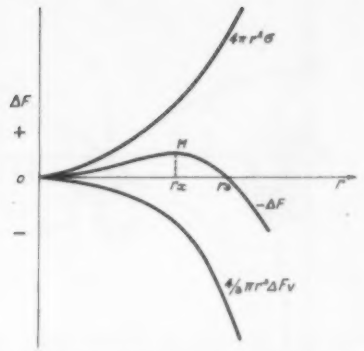

Fig. 1 — Change in free energy with the solidification of a spherical particle of radius r.

HETEROGENEOUS NUCLEATION (FOREIGN NUCLEI)

Industrial metals and alloys generally solidify with a small amount of undercooling. Since this solidification temperature is considerably higher than that required for homogeneous nucleation in pure metals, the role of foreign nuclei must be recognized. These nuclei may occur from reactions or precipitations of the elements present in the melt, or may be suspended solid particles entirely foreign to the metal. The importance of the crystal structure of the particle in this regard must be emphasized.

SINGLE PHASE AND POLYPHASE SYSTEMS

Pure metals and solid solutions are solidified by the nucleation of a single phase. Solidification is controlled by the number of effective nuclei per unit of time and volume, and by the rate of growth of the single solid phase. The preponderant influence of the nucleation factor is proved by the fine grain produced whenever the maximum number of nuclei are produced naturally (by solidification in pure metals with a large amount of undercooling) or artificially (by effective inoculation of metals and alloys).

Polyphase crystallization is more complex, since each phase must be nucleated separately. One phase *A* may solidify without difficulty and without undercooling, whereas another phase *B* may undercool considerably because of lack of effective nuclei. This will cause a lag in solidification that will considerably influence the structure of the alloy. It is also possible that phase *A* will act as a foreign nuclei for the nucleation of phase *B* and impose its orientation upon phase *B*, such as occurs in simultaneous crystallization. To remain within the scope of the title, only eutectic solidification will be considered as the most appropriate example of polyphase solidification.

EUTECTIC SOLIDIFICATION AND RESULTING STRUCTURES

Eutectic solidification, as with any industrial alloy, occurs with a small amount of undercooling

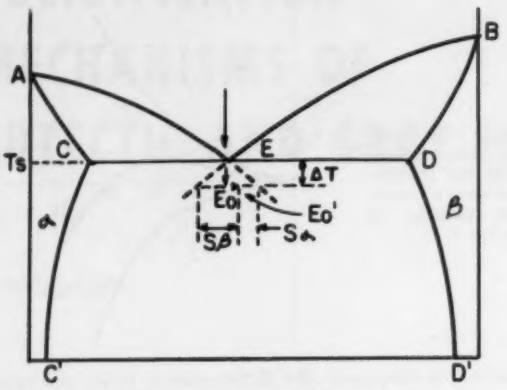

Fig. 2 — Solidification eutectic (arbitrary scale of ΔT).

(Fig. 2). Each of the two phases, α and β, require stable nuclei to solidify. Except for the exceptional simultaneous solidification of the two phases from the melt, or unusual instances when the same nuclei can serve both phases simultaneously, one of the two phases will be nucleated before the other. If the α phase solidifies first at a temperature of $T_s - \Delta T$ (when the liquid reaches point E_o in Fig. 2), then effective nuclei of the α phase develop simultaneously at numerous points in the melt at this temperature.

These nuclei initiate the solidification of α grains, and each is surrounded by a liquid zone impoverished in element *A* and enriched in element *B*. The average concentration of the volume of liquid surrounding each grain of α has been moved from E_o toward E_o'. As the solidification of α continues, the supersaturation of the liquid with respect to β will increase as the composition of the melt moves towards the right until sufficient supersaturation occurs to force solidification of β. Thus, eutectic solidification is initiated, and the first β crystals will be formed in the immediate vicinity of the α crystals.

Based on the foregoing considerations, two possibilities for eutectic solidification can be postulated:

1) Alternate solidification of the two phases of the eutectic occurring with alternate displacement of the composition of the surrounding liquid from left to right, and from right to left of the average composition.
2) Simultaneous solidification of the two phases with a common solidifying front advancing into the liquid, which is supersaturated with respect to the two phases.

Normal eutectic lamellae result from solidification following the second hypothesis; abnormal eutectics more closely follow the first hypothesis.

Normal Eutectics

The mechanism of normal eutectic solidification such as the Al-Zn eutectic and the ferrite-cementite eutectoid is well known. These are clearly instances of simultaneous growth of the two phases advancing in a common front. This mechanism is illustrated for the growth of pearlite into austenite in Fig. 3. It has been proved that pearlite is nucleated by the cementite, and obtains its orientation from the cementite.

This mode of secondary nucleation is applicable to all normal eutectics. The phase that is nucleated first nucleates the second phase, and imposes its orientation upon this second phase. As a result, the growth of normal eutectics obey the laws of M. Straumanis[4] and N. T. Belaiew,[5] which actually are only corollaries of the means of nucleation.

According to the results of the research of Straumanis[4], all the plates of the first phase have the same crystal orientation, and form a constant angle with the plates of the second phase. It is not an exaggeration to refer to a pearlitic grain or a eutectic grain of this type, since it is similar to two single crystals cut in slices and associated as alternating planes in the same crystal structure.

The law of Belaiew[5] is better known to the ferrous metallurgist. This law points out the constant interlamellar distance between the alternating plates of pearlite within the same grain. Furthermore, when the plates or lamellae are straight, it can be verified that the interlamellar distance is a function of the temperature of formation.

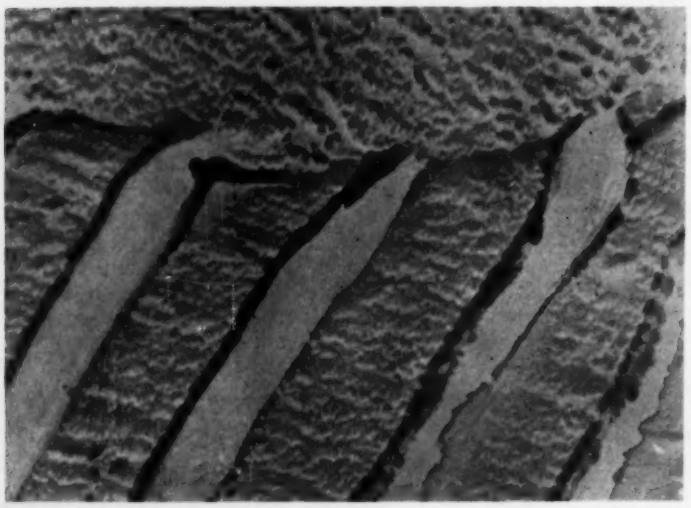

Fig. 3 — Crystallization front of the normal pearlite eutectoid. 30,000 ×.

Abnormal Eutectics

Partial or Total Envelopment. E. Scheil[6] cites five examples of abnormal (anomalous) eutectics: Austenite-graphite, Al-Si, Al-Al_3Fe, Zn-Zn_3Sb_2 and Pb-Ag. These five cases present common characteristics.

1) The primary or enveloping phase clearly predominates in mass and volume.
2) The secondary or minor phase has a higher solidification temperature than the primary phase. This difference is large with graphite and austenite and Al and Si, but is small with Zn and Zn_3Sb_2.

The laws of Straumanis and Belaiew do not apply to these anomalous eutectics. This is clearly not a case of simultaneous solidification of the two phases. If the conditions of simultaneous growth are not fulfilled, the importance of the time lag between the solidification of the two phases is of interest.

Thermal analysis of the solidification of abnormal eutectics shows the existence of a eutectic stage with characteristic undercooling, although it is slight and always followed by a rise in temperature. This indicates a delay in solidification of the secondary phase, shows also that the primary phase is not nucleating the secondary phase and shows the lack of nuclei for the secondary phase in the melt. These conditions hold for the five anomalous eutectics listed. In all of these cases, the anomaly results because the major phase is incapable of nucleating the minor phase.

Second Phase Solidification

When solidification of the second phase does begin, it is usually at a relatively small number of locations, indicating a small number of effective nuclei. However, the speed of solidification is rapid, and the secondary phase forms quickly. This rapid solidification produces a local supersaturation of the first phase in the eutectic liquid at the interface of the secondary phase and the liquid. This tends to cause envelopment of the second phase by the first.

The mechanism of this eutectic reaction is illustrated at the *A*, *B* and *C* stages in Fig. 4 for the solidification of plates or flakes of the second phase. Stage *A* represents the rejection of the first particle of the β phase. As a result of the solidification and growth of the β particle, a concentration gradient is established in the surrounding liquid with its steepest slope perpendicular to the surface of the β plate. This produces a solidification of the α phase, as shown under *B*, and the envelopment of β starts to become apparent.

As the β plate continues to grow, it spreads towards the limits of its zone of influence (limited by the existence of neighboring plates), and its speed of growth decreases permitting greater envelopment by the major phase. The stage of quasi-complete envelopment, marked by stopping the growth of the β plate, is finally achieved in *C* (Fig. 4).

The three phases, liquid, α and β are in contact during the entire period in which the β phase is growing. Cooling curves of this melt would show a hold during this period, since this is a real eutectic solidification. However, the appearance of the solidified structure is considerably different from that of

Fig. 4 — Schematic representation of abnormal eutectic crystallization. *A, B, C:* minor phase (β) in plates.

a normal eutectic which occurs with the simultaneous growth of the two phases. The structure of an anomalous eutectic is illustrated for the Al-Si eutectic in Fig. 5.

This photomicrograph also contains some primary silicon phase present as polyhedral crystals. The form and distribution of the silicon phase in the eutectic resembles the form and distribution of graphite flakes in gray iron.

Minor Phase Spheroid Solidification

If, instead of solidifying in plates or flakes, the minor phase solidifies as spheroids, or in some form without a preferential direction of growth, a more rapid envelopment by the major phase can be visualized. This will produce an abnormal eutectic with total envelopment, and will appear as numerous β particles in an α matrix. If, in the case of anomalous solidification with partial envelopment, the undercooling of the minor phase is forcibly increased, early total envelopment may result.

Undercooling of the silicon phase of the Al-Si eutectic can be accomplished by the addition of sodium. This is the result of poisoning of the foreign nuclei of the minor silicon phase. This modification in structure is universally employed to improve the mechanical properties of this alloy.

Fig. 5 — Abnormal Al-Si eutectics. 100 ×.

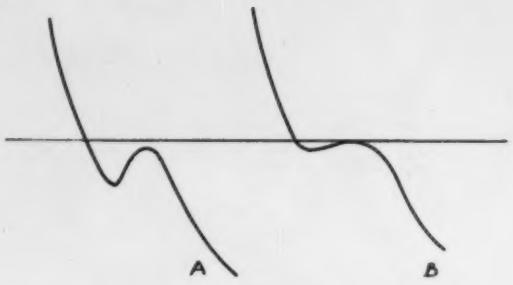

Fig. 6 — Schematic representation of the steps of eutectic solidification of irons *A* and *B*.

EUTECTIC SOLIDIFICATION OF GRAY IRON

(Anomalous Austenite-Graphite Eutectic)

If the cooling curves are traced for

A) a relatively pure, synthetic Fe-C-Si alloy, and
B) an industrial gray iron with comparable C and Si contents,

the cooling curves shown in Figs. 6a and 6b, respectively, are obtained. Examination of the graphite structure of these two irons will show:

A) Graphite of the supercooled type for pure Fe-C-Si alloy.
B) Normal flake graphite (such as Type A) for the industrial gray iron.

These results may be interpreted based on the preceding theory. If the two irons were hypoeutectic to the same degree (had the same carbon equivalent), eutectic solidification was preceded by the rejection of primary austenite. Eutectic solidification is not initiated when the equilibrium eutectic temperature is attained, since the state of nucleation of the eutectic liquid with respect to graphite is insufficient. However, the solidification of the austenite continues. The two irons have behaved in a similar manner up to this point, but the amount of supercooling obtained for the two is different. Even though this difference is small when expressed in degrees centigrade, it produces widely different results during eutectic solidification.

Case A

When the solidification of case *A* is considered, appreciable undercooling is proof of the absence of nuclei capable of initiating the solidification of the graphite. It is probable that the graphitization is started by spontaneous or homogeneous nucleation. This hypothesis, or one requiring the action of less effective foreign nuclei than those which cause the graphite nucleation in the industrial gray iron (Case B), explains the undercooling and the nucleation and simultaneous growth of the great number of nuclei with regular distribution, as observed in these undercooled irons.

The great number of graphite particles implies a small zone of influence of each and rapid envelopment by the major austenitic phase. This eutectic is definitely an anomalous one with quasi-total envelopment. It is definitely not a normal eutectic, and does not follow the laws of Straumanis[4] and Belaiew.[5]

The industrial gray iron *B*, or a pure Fe-C-Si alloy to which sulfur is added according to Boyles[7] demonstrates less undercooling, and solidifies as a eutectic of austenite and flake graphite. It behaves as an anomalous eutectic with partial envelopment similar to the Al-Si eutectic in Fig. 5. However, the real supercooling is greater than the apparent supercooling expressed as the temperature difference between the maximum and minimum of the eutectic arrest. It is considered, as a first approximation, that the mechanism of this austenite-graphite eutectic is that expressed in *A*, *B* and *C* of Fig. 4.

The apparent undercooling of the eutectic in the industrial gray iron (Fig. 6b) is small, and difficult to detect at times. This proves the existence of a good condition of nucleation for the graphite phase in the melt. Nucleation is probably produced by the presence of foreign nuclei which only require slight undercooling of the eutectic liquid to become effective. The effectiveness of sulfur in producing nucleation of flake graphite is noted by W. Patterson.[8] This work points out the frequent association of graphite flakes and the FeS or xMnS•yFeS inclusions.

However, if the industrial gray iron is superheated to a considerable degree, the ability to nucleate the graphite is lost, even though the sulfur content is unchanged and its distribution and appearance remain similar. It seems probable that the superheating may have destroyed or poisoned effective foreign nuclei other than the sulfur. Intervention by sulfur is undeniable, but it is believed to have another explanation.

Sulfur Effect

Research work by K. Grueter and B. Marincek, and more recently work by R. Gautschi[10] have shown that sulfur reduces the surface tension of liquid iron and, in general, the intersurface tensions. However, sulfur is practically insoluble in solid iron, and the sulfur not combined in the sulfides (xMnS•yFeS) is pushed into the liquid phase at the austenite-liquid interface, concentrates at this location (slow diffusion rate) and lowers the local temperature of solidification. At the same time, this concentration of sulfur increases the fluidity and reduces the surface and interface tensions. Accordingly, the nucleation of graphite is facilitated since by equation (1):

$$-\Delta F = -\Delta F_v + \sigma S$$

Therefore, in the presence of sulfur certain foreign nuclei are effective. If the liquid iron is superheated, the sulfur remains but these foreign nuclei are destroyed or poisoned. Graphite does form during the solidification of this superheated liquid iron, but sufficient undercooling is necessary to force either homogeneous nucleation or nucleation from less effective foreign nuclei.

EUTECTIC CELLS

The preceding general considerations are only concerned with the shape and dimensions of the graphite. Another important consideration is the distribution of the graphite, for example the rosette or type *B* classification. Each rosette corresponds to a center

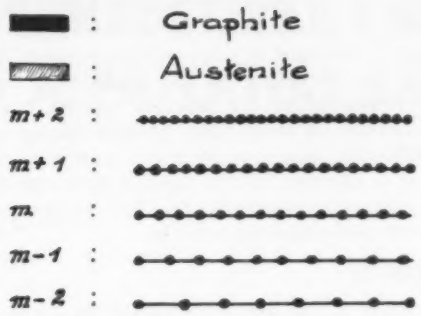

Fig. 7. — Legend of symbols used in Figs. 8a, 8b and 8c.

of crystallization from which a colony develops. These colonies correspond to eutectic cells and they are not numerous. This indicates that the first stage of solidification of the graphite occurred at a small number of effective nuclei.

However, the regularity of dimension and distribution of the colonies indicate that nucleation of the graphite was caused by the supersaturation of the liquid in the vicinity of the solidified austenite, not by general supercooling. In the latter case, the number of nuclei occurring simultaneously is generally great as in the case of supercooled graphite and, to a lesser degree, Type *A* graphite.

Considering a theoretical case of a small volume of perfect radial isotropism from the point of view of temperature, composition, etc., successive stages of radial graphite crystallization starting from a graphite nucleus may be represented by Figs. 8a, 8b and 8c. Figure 7 shows the significance of different items in Fig. 8. The first step considered in Fig. 8a is for the first small graphite particle nearly totally enveloped by austenite.

CARBON DIFFUSION

At this point, the surrounding liquid will be chemically heterogeneous because of the limited diffusion rate of the carbon. The liquid is also physically heterogeneous because of the temperature differences. Considering only the concentration of carbon, it is possible to trace the curves (surfaces) of concentration in the liquid

$m + n \cdots m + 2$, $M + 1$, (positive carbon concentration) where m = average concentration at the limit of the zone of influence,
$m - 1$, $m - 2 \cdots m - n$ (negative carbon concentration, i.e., lower than average). It is evident that the maximum carbon concentration gradient is established around the xx′ axis, and that the maximum concentration is located at the intersection of this axis with the surface of the austenite crystal which tends to envelop the graphite completely.

The next particle of graphite, then, should precipitate at this point of intersection except for the fact that the temperature gradient being at a maximum on this axis is opposed. Thus, it is probable that the next particle of graphite will be nucleated on the xx′ axis at a small distance from the surface of the austenite, and will grow along the xx′ axis of maximum carbon concentration gradient. A similar line of reasoning shows that the next austenite will develop along the yy′ axis.

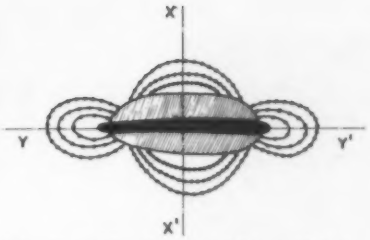

Fig. 8a — The first graphite particle is nearly enveloped by austenite.

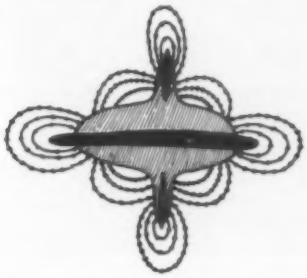

Fig. 8b — The progressive growth of the eutectic cell implies progressive envelopment of new graphite particles by the major austenite phase along the axis xx′.

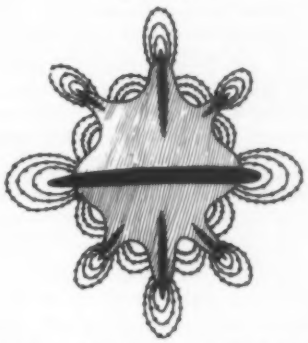

Fig. 8c — Third stage of eutectic solidification development.

As growth of the eutectic proceeds, the new graphite particles will be enveloped by the major austenitic phase growing along the xx′ axis of each graphite flake. This second step is shown in Fig. 8b.

A continuation of this reasoning results in the step shown in Fig. 8c. This is the last drawing that is presented because they become too complicated, and the successive development of the eutectic cell can be easily imagined. The drawings in Figs. 8a, b and c can now be compared to the actual rosette pattern of a eutectic cell shown in Fig. 9. The difference in these structures appears large at first glance, but this can be explained as follows:

1) Perfect radial isotropism was presumed in the drawing for simplicity. In practice, however, this perfect radial isotropism does not exist in either temperature or concentration. This explains why the actual flakes are curved and not perfectly radial in direction.

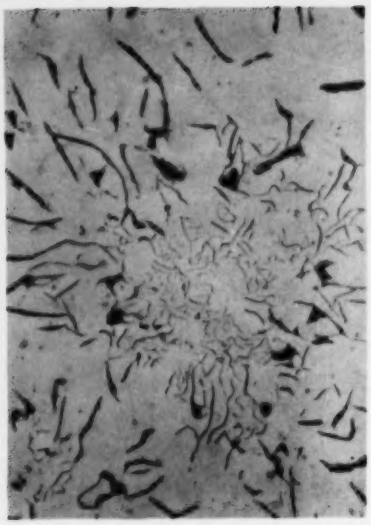

Fig. 9 — Graphite rosette (type B, A.S.T.M.).

2) The rosette shown is not necessarily cut through the center of the eutectic cell.

3) It is noted that the graphite flakes are fine at the center of the cell, increase to a maximum thickness and then decrease in size toward the limits of the rosette. The increase in the dimension is caused by segregation of the sulfur, and the final decrease at the outside of the rosette is the result of interpenetration of the zones of influence of the various rosettes during the final stages of solidification.

4) The photomicrograph of the rosette in Fig. 9 shows a central zone of fine graphite without a distinct radial direction. All of these small flakes formed at the start of eutectic solidification. These flakes take the place of the single large central flake shown in the drawings in Figs. 8a, b and c. The number of these flakes formed during initial solidification may vary from one to several dozen, and is a function of the state of development of the primary austenitic dendrites at the time of nucleation of the eutectic graphite.

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THE INDUSTRIAL ENGINEER AS A POTENTIAL EXECUTIVE

By M. E. Mundel

ABSTRACT

Industrial engineering, broadly conceived, is a built-in management development program in a company. This concept of industrial engineering allows the smaller company to attract men of real ability, will help reduce the management-staff rift, and provides the necessary background for potential managers.

INTRODUCTION

Most recently one of the consulting assignments of the author's company has been with a small jobbing machine shop which specializes in a particular type of work. It is hoped that assistance can be given to make this organization profitable again. A basic lesson is contained in an examination of how it reached its present plight of operating at a loss.

The shop operated for many years doing its particular type of work. There was an abundance of this type of work available and a shortage of such jobbing shops. They did well. As the volume of work grew, some of the plants which were sources of such work grew to a size where they found it profitable to purchase their own specialized machining equipment, and their work no longer went to the jobbing industry. There was recently, from the above cause, about a 10 per cent reduction work available for the industry.

As you might anticipate, the ten per cent reduction did not hit the various jobbers across the board; it hit the high-cost shops and this shop was one of them. Their work almost disappeared over-night. A long hard struggle lies ahead as the type of management is developed that will put this shop back in the black. It is my contention that the basic lesson to be learned is the danger of failing to continually develop a cost-conscious management.

In a way, it is the advent of occurrences of this type, as well as the wishes to avoid them, that has given rise to the enormous growth of executive development plans within the larger companies, and to the growth of executive development courses at various University extension divisions to serve the companies who are not large enough to organize their own plans.

I do not blame the plight of the mentioned company on conditions within the industry; I say that this organization failed to develop executive leadership and use this leadership to keep them from getting into this "bind." I should add, in all fairness, that present management is aggressively attacking the problem and is also developing a management team to safeguard the future.

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EXECUTIVE DEVELOPMENT

But how do you develop executive or managerial personnel? Most business has only recently become concerned with this problem.

> Throughout the latter half of the nineteenth century, which saw the blossoming of industrial capitalism, enterprises were bound to individuals. Although the modern corporation was firmly established in law and in certain sectors of the economy long before the end of the century, the smaller individual and family companies, rather than the large, impersonal corporation, typified business enterprise — even during the second half of the nineteenth century. Under these circumstances there was no special problem connected with the selection and development of executives. The man who made his little business grow into a large institution remained at the head of the organization when it expanded. Eventually, the responsibility for ownership and management was transferred to his son or son-in-law.[1]

The changing nature of our society, and the changing manner of performing our industrial work, have brought the problem of the executive to the foreground. Executive responsibility may no longer be simply handed to an untrained individual like a mere piece of property. The executive who is to receive the responsibility must be trained to receive it or he will more likely be a receiver.

MANAGEMENT RESPONSIBILITY

Management is, after all, the task of designing, predicting the performance of, controlling and providing the facilities for an integrated human-group activity, the related physical facilities and the inter-relationships between the two.

The continually increasing mechanization, the growth of unions and the various additional social restrictions on activities have made continually the task of management more complex. Competition, as it increases, adds to the problem.

> If, as many managements believe, competition is going to be more rigorous in the years ahead, then the supply of future executives becomes more critical. The competitive edge will be in the caliber of a company's executives. But executives for ten years or more in the future must be recruited today.
>
> Most companies recognize this need, and so we have been witnessing a massive talent hunt.[2]

The basic contribution of the manager is the making of the decisions necessary to accomplish assigned or assumed objectives within the task of management.

MANAGERIAL LEVELS

Within any organization, managers operate in three somewhat indistinctly separated "decision areas." These are usually associated with three different "levels" of management, which also have somewhat hazy borders, although in a small organization an individual may "wear several hats." The three decision areas and managerial levels are:

a) Top managers. Those who make decisions concerning the relationship of the organization to external economic, situational and political factors. These decisions lead to broad statements of policy or objective.

b) Middle managers. Those who make decisions concerning how, within the policy framework, to achieve the broad objectives. These decisions result in plans for action and this group is often the one most commonly identified as "operating managers."

c) Supervisory managers. Those who make decisions concerning the day-to-day carrying out of action plans.

In the usual organization, each level of management may have staffs (individuals acting data gathering or data digesting extensions of the managers), particularly when either the complexity of the data on which the decisions are based (decision difficulty), or the number of decisions per unit of time (decision density), exceeds the capacity of the individual with the decision making responsibility.

Staff Duties

These staffs, in general, attempt to alleviate the effect of high decision difficulty, high decision density or a combination of both, by activities such as:

1) Dimensioning management designs by means of work count, work measurement, quality specifications, etc.
2) Routinizing and channeling information to reduce legwork and to compile the necessary managerial data into comprehensible form.
3) Making management designs (such as job methods, procedures, production sequences, etc.) to eliminate minor decisions from clogging organization channels.
4) Monitoring and reporting on conformance of management designs and organization performance, both to assist supervisory managers and to evaluate action plans, as well as to provide a comprehensible experience basis for future policies and plans.
5) Recommend many decisions to top and operating managers based on their (the staffs) concept of the objectives.

And if we consider the foregoing five levels of managerial staff as a hierarchy of management, then we could appropriately add:

6) The manager who makes the decisions.

Industrial Engineering

The first five levels in the hierarchy are frequently referred to as "industrial engineering" functions, although there may be other staffs who also perform some of the same functions in different activity areas. However, these other staffs lack the closeness to production, and production is where the basis of costs really lies.

Those of you who come from small organizations may be saying, "This does not apply to me; I cannot afford so many people." Only the last half of this statement is true. You cannot afford the people, but you have the functions and they must be performed.

Before we continue with this, I made an implication concerning industrial engineering which I think is worth examining at greater length.

In all too many cases, industrial engineering is considered as another name for time study and relegated to the role of a somewhat difficult, clerical function. I firmly believe that those who take this position are denying themselves not only tremendous services but also cutting off one of the vital sources of potential executives.

It is interesting to see what Don Burnham, Vice-Pres. of manufacturing of the Westinghouse Corp., has to say about this:

> You may wonder at this point what I consider industrial engineering to include, and this is a logical question. There is certainly little agreement throughout industry regarding the exact boundary lines of the functional department called Industrial Engineering. This unusual situation itself is primarily attributable to the rapid growth of the function. As certain sub-functions have developed, they have become sufficiently important to be segregated as self-sustaining individual departments.
>
> Compounding the confusion which sometimes exists is the fact that different sub-functions reach this level of importance in different industry or product situations. It is not uncommon to find a plant with separate staff departments for Quality Control, Production Control, Inventory Control, Work Measurement, Methods Engineering, Plant Layout, and others. Such splits, however, do not indicate a weakness in the industrial engineering function. To the contrary, they serve as evidence of the degree to which the function has become indispensable to the manufacture of any products.
>
> You can see, then, that I am considering industrial engineering in the broad sense. That is, it includes all applications of scientific principles to the planning, operating, and control of the complete manufacturing operation.[3]

MANAGEMENT TRAINING

The people who perform these industrial engineering functions are those that really serve as staff to the managerial group, be the group large or small. But not only do they serve the executives, but more important, they "train" so to speak, under them. As the staff grows in ability they come closer and closer to the actual executive function; *viz,* as they move up through the hierarchy previously given. In some cases, the upward movement is carefully planned. We find more and more notes appearing, as follows:

> Are your foremen a little weak on time standards? It's no problem at Worthington Company's Compressor and Engine Division (Buffalo, N. Y.). There every foreman comes up from the ranks. But no

> foreman goes directly from the ranks to the foreman job. He first spends two years as a standards man.[4]

It would appear as though industrial engineering, broadly conceived, is the ideal, built in, management development program that most companies already possess. Further, such a concept of industrial engineering, by providing a greater goal for the engineers, allows even the small organization to attract men of real capability. Further, the use of this staff as the future management potential line, will assist in reducing the rift that sometimes exists between line and staff, thus making both more effective.

DISADVANTAGE

The only drawback to thinking of industrial engineers as future executives seems to be the thought that good engineers, once you get them, will be drawn eventually away from the industrial engineering work and thus, be lost to the function. I think this is somewhat academic, because if the job is a dead end, you will probably never get them in the first place. But more seriously, if the industrial engineer eventually becomes a manager, certainly he is in a position to make use of an aggressive staff. And a continually aggressive management is required if a organization is to stay alive.

CONCLUSION

If we consider the manner in which an effective management operates, then it seems only natural that the present industrial engineers are the potential executives, provided the industrial engineering function is broadly conceived, soundly staffed and properly used. Then, not only will it assist the organization now, but it will also be an executive development program for the future.

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ALUMINUM ALLOYS FLUIDITY TEST

fluidity tripled with new mold coating

By M. C. Flemings, H. F. Conrad and H. F. Taylor

ABSTRACT

Still another fluidity test is described herein, to be added to the already large number of such tests developed in past years. This is a relatively simple sand mold type test which is especially well adapted (because of the accuracy and reproducibility of test results) to research and development work, but is equally suitable as a foundry control tool. The test piece combines the desirable simple features of other types and includes a metal screen in the runner (in conjunction with a carefully designed sprue and pouring basin) to regulate entrance velocity and provide clean dross-free metal in the spiral.

The above test piece was used to determine:

1) The effect of pouring temperature and alloy composition on the fluidity of aluminum-copper alloys.
2) The relative fluidities of several commercial aluminum alloys.
3) The effect of mold coatings on the fluidity of aluminum alloys.

Of all mold coatings tested hexachloroethane proved to be the most spectacular in its effect; for example, using a coating 0.006 in. thick, the fluidity of aluminum-4.5 per cent copper (at 1330-1305 F) was improved 200 per cent (e.g. tripled). Among the other coatings tested were carbon-black, graphite, gypsum and zinc carbonate.

It has been concluded that one important function of certain of these coatings is to decrease heat flow (act as insulators). However, other factors may also be important such as reduction of surface tension of the metal and alteration of the character and/or amount of the oxide film which, in aluminum alloys, tends to form at the tip of the flowing stream.

Hexachloroethane improved the fluidity of all alloys tested, including high purity aluminum, 195 alloy (high purity), 356 alloy (high purity), 220 alloy and an aluminum-zinc commercial alloy (40E). Studies using a large, thin, plate casting gave ample, practical proof that the beneficial effect of the coating extends to commercial type castings and is not a laboratory curiosity limited to test spirals.

INTRODUCTION

To meet the design requirements of modern aircraft and missiles, strong, sound aluminum castings must be produced in thinner sections than have heretofore been considered possible. Fabrications are sometimes chosen in preference to castings (even at much greater cost and trouble) simply because castings cannot be made thin, and hence, light enough to meet requirements.

The difficulty in producing thin castings (under 1/8-in.) is due primarily to inadequate metal "fluidity"; the metal solidifying before completely filling thin mold cavities. Metal fluidity is increased in practice by judicious choice of alloy composition, and by providing additional superheat to the melt. However, there are limitations to these techniques, and few foundries can produce aluminum castings with extensive sections much less than 1/8-in. thick.

In July, 1957, a research program was sponsored at Massachusetts Institute of Technology by the U.S. Army Ordnance Dept. through Pitman-Dunn Laboratory, Frankford Arsenal, to obtain a basic understanding of the factors affecting fluidity in aluminum alloys and, if possible, to develop practical methods for increasing fluidity. This paper describes one phase of the initial research; dealing with 1) development of an accurate and reproducible sand mold fluidity test for aluminum alloys, 2) a measurement of the relative fluidities of several typical aluminum alloys using the test method developed, and 3) a study of mold coatings effects on fluidity in sand molds.

A parallel program, also under Frankford Arsenal sponsorship, was conducted to determine how metallurgical factors ("mode of solidification") of aluminum and its alloys affect fluidity. This study has been carried out with the "vacuum fluidity tester" developed by Ragone, Adams and Taylor[1,2] and used at M.I.T. and elsewhere in several earlier researches.[3,4] Results of this aspect of the present fluidity research are published elsewhere[5,6] and will not be presented herein.

FLUIDITY TESTING

Fluidity, in the casting sense, refers to the property of a metal which allows it to flow into a mold. It

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is usually defined as the distance metal flows when poured into a standard fluidity test channel. This channel may be straight or it may be in the form of a spiral, and the cross-section of the channel may be round, half-round, trapezoidal or rectangular.

T. D. West,[7] in 1902, was the earliest investigator to report on the flow characteristics of molten metals cast into sand molds. He poured metal into a horizontal wedge and considered the distance flowed as a measure of fluidity. Ledebure,[8] in 1904, Sexton and Primrose,[8] in 1911 and Moldenke,[9] in 1917, modified the wedge test somewhat.

Ruff[10] ran metal in a long cylindrical channel, and used the length of flow as his value of fluidity. This test was particularly sensitive to errors in leveling. Evans[11] tried an inverted "U" type of test in which he used several vertical sections of various cross-sectional areas fed from a common channel. The heights to which the metal rose in the various sections were a gage of fluidity.

Fluidity Spiral

The familiar fluidity spiral was first tried by Saito and Hayashi[12] in 1919; their method simplified handling and leveling problems. Many investigators have improved upon this spiral type test; the two best known modifications being those of Saeger and Krynitsky[13] for cast iron, and of Taylor, Rominski and Briggs[14] for steel. These spirals are now accepted in America as standards for determining fluidity of ferrous metals.[13,17]

Eastwood and Kempf,[18] and later Sicha and Boehm[19] developed a spiral casting of flat cross-section for studying fluidity of aluminum and its alloys. Only a limited amount of experimental work has been done with this fluidity test, but results to date indicate it is not sufficiently reproducible for research and development work.[16] A "star" type fluidity test piece has been developed by Kondic.[20] It, too, is a relatively recent development which must yet stand the test of time.

A new approach in fluidity testing was developed by Ragone, Adams and Taylor.[1,2] They developed a "vacuum fluidity test" in which the liquid metal was drawn into a pyrex glass tube by means of a vacuum. Variables of this test were determined experimentally and analytically using low melting point alloys. Later investigators have employed this method in precise determinations of the fluidity of magnesium and its alloys,[3] and of aluminum alloys.[4,6]

Several excellent, comprehensive bibliographies of the history of fluidity testing have been prepared; the reader is referred to these for more complete coverage of the subject.[15,16]

FLUIDITY OF ALUMINUM AND ITS ALLOYS

Until recently, interest in metal fluidity has been concentrated largely in the field of ferrous metals. Fluidity tests have been developed and are used commercially as quality control checks to determine the flowing qualities of molten metal. Fluidity tests are used in some ferrous shops in place of temperature measurement.

Fluidity testing of aluminum alloys has been less important as a shop control technique because temperature measurement has appeared to be an adequate gage of the running qualities of a given alloy. Also, such temperature measurement is accurate and reliable, and until recently fluidity tests for aluminum alloys were either quite complicated or yielded results which were difficult to reproduce.[16]

Courty,[21] in 1931, measured the fluidity of various aluminum alloys in a carefully designed spiral test mold using a bottom pouring basin stoppered with two fusible lead plugs. While the arrangement was well designed for the use intended, it does not appear adaptable as a standard fluidity test because of its relative complexity.

In 1939, Eastwood and Kempf[18] developed the fluidity spiral of flat cross-section described above. Cross-section of the channel was 1¾-in. wide by 1/16-in. thick. A simple ¾-in. diameter downsprue was used with an overflow pouring basin. Sicha and Boehm[19] later modified the design by adding a "well" at the bottom of the sprue and adding a piece of tinfoil to serve as a temporary "dam," thereby reducing the influence of any variation in pouring. While these modifications were said to result in improved uniformity of experimental runs, nonetheless, fluidity spiral weights for duplicate runs varied by as much as 15 grams, in an average total spiral weight of only 60 grams.

Investigation Results

Experimental results of the above investigations included 1) a comparison of the relative fluidities of several commercial foundry alloys, and 2) data illustrating that dissolved gas content and remelting had little or no effect on fluidity of aluminum alloys.

Kondic and Kozlowski[22] later developed an apparatus for bottom pouring aluminum spirals in a metal fluidity mold. The metal was melted in situ, and at the desired moment a stopper rod was lifted and the aluminum allowed to flow into the mold cavity. The mold was heated with electrical elements to any testing temperature desired. Fluidity data were obtained for aluminum-silicon alloys from 0 to 16 per cent silicon, illustrating that optimum fluidity is obtained with pure metals and with eutectics. The authors also showed that modified aluminum-silicon alloys possess considerably lower fluidity than unmodified alloys. This latter conclusion has recently been confirmed by Kondic using his new "star" fluidity test pattern.[20]

Vacuum Fluidity Test

Utilizing the "vacuum fluidity test," Ragone and Floreen[4] investigated the fluidity of a series of aluminum-copper alloys, and aluminum-magnesium alloys. Both alloys were investigated in the region of 0 to 33 per cent solute. Results obtained for the aluminum-copper system were qualitatively similar to those obtained by Courty[21] with his quite different fluidity test. In the work of Ragone and Floreen, fluidity was found to vary inversely with solidification range; solidification range was calculated from nonequilibrium considerations in the manner used by Niesse, Flemings and Taylor[3] in their study of fluidity in magnesium alloys.

Fig. 1 — Single spiral fluidity casting with gating system.

DEVELOPMENT OF SAND MOLD FLUIDITY TEST

The "vacuum fluidity test" wherein metal is drawn out of a crucible directly into a glass (or metal) fluidity channel has been found to be ideal for studies of the effect of solidification variables on fluidity. In addition, when glass tubes are used, motion picture photography can be utilized to follow the progress of metal during the test. The major disadvantage of the test, however, is that it does not readily permit study of the effect of mold or mold-metal variables on fluidity. For example, study of the effects of sand grain size, moisture content or mold coatings on fluidity requires the use of a more standard sand mold test. In addition to being able to measure effects of mold and mold-metal variables, a reproducibile sand mold fluidity test would be expected to closely relate to actual conditions of casting.

After carefully evaluating the various test pieces developed to date it was decided no single one was simple enough for extensive testing and also for giving test results accurate enough for laboratory investigation. Accordingly, it was decided to develop a new type test which would be simple and easy to use, and would also:

1) Afford precise control over metallostatic "head," and permit this pressure head to be reached before any metal entered the fluidity spiral.
2) Provide control over metal turbulence as the metal entered the spiral.
3) Filter any dross or other foreign materials from the metal before the metal entered the fluidity spiral and do so without altering the metal "head."
4) Be of flat cross-section to simulate problems encountered in pouring sand castings of thin section in the foundry.

Single Spiral Mold Design

The fluidity test initially developed to meet the above requirements is illustrated in Figs. 1 to 5. Figure 1 shows a cast spiral with pouring basin, sprue, runner and gate attached. The pouring basin is designed with an overflow to maintain constant metal head during pouring, and the sprue is tapered to minimize tubulence and aspiration of air. After passing through the sprue, metal enters a large runner and passes up through a screen to remove dross. It then travels through a vertical gate and into the spiral. The large runner serves to minimize turbulence and to remove dross (by permitting a screen to be molded in); its primary purpose, however, is to permit a time delay so that constant "head" is obtained before any metal enters the fluidity spiral. A somewhat similar arrangement has been described by Prussin and Fitterer.[23]

Figures 2 to 5 provide details of the test equipment. The runner (with screen) is made as a core but the spiral itself is formed entirely in the sand mold (Fig. 2), which for this investigation was green sand. The

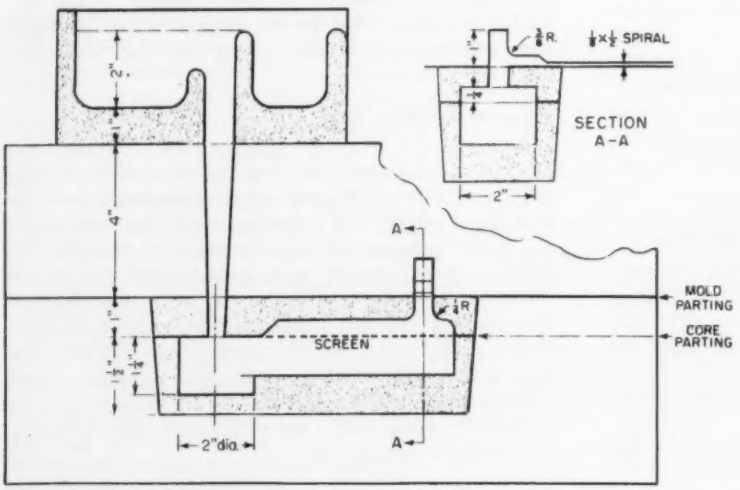

Fig. 2 — Schematic diagram of single fluidity test mold.

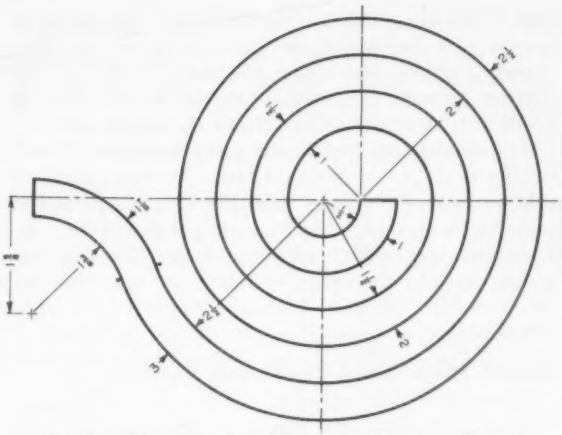

Fig. 3 — Diagram of fluidity test channel which is ⅛-in. thick.

spiral (Fig. 3) is of rectangular cross-section and is 28 in. long x 0.50 in. wide and 0.125 in. thick. Figures 4 and 5 are photographs of the matchplate pattern, dry sand pouring basin and dry sand cores and screen used in the gating system. The screen is of tin plated steel with holes $\frac{1}{16}$-in. diameter. Perforations account for approximately 50 per cent of the area of the screen.

Sprue Design

The sprue employed tapers from ¾-in. square at the top to ½-in. square at the base. The area of the sprue base is small enough to permit the pouring basin to be filled to its maximum level before any metal enters the spiral itself. This fact was verified by placing a thermocouple at the entrance to the spiral and observing the height of metal in the pouring basin at the moment flowing metal first contacted the thermocouple. Approximately 2½ sec elapsed from start of pour until the metal reached the spiral entrance.

The test piece described above was found to satisfy all the essential preliminary requirements; the molten metal reached the spiral free from dross, flowing smoothly at a constant rate, and under a constant pressure head. Radiographic examination showed the spiral castings to be entirely dross free.

Single Spiral Mold Accuracy

Accuracy and reproducibility of the test piece were checked by pouring 1) 18 test castings of aluminum-4.5 per cent copper alloy, varying only the pouring temperature, and 2) 20 test castings in which copper content as well as pouring temperature was varied.

In this phase, and throughout the entire study, molds were hand rammed in a 14 in. x 18 in. aluminum snap flask. Molding material used was synthetically bonded green sand (140 N. J. Silica Sand). A ½-in. diameter vent hole was provided at the end of each spiral to allow mold gases to escape. Baked core sand bonded with urea formaldehyde was used to form the pouring basin and runner cores.

Melting was done in a gas-fired crucible furnace. All alloy compositions were prepared using aluminum ingot (99.9 per cent) and 50 per cent aluminum-50 per cent copper master alloy. Master alloy was added shortly after meltdown of the aluminum ingot. No grain refiners were used. Each melt was degassed by bubbling dry nitrogen through the metal for at least ten min at 1300-1350 F (while metal continued to heat in the furnace). Melts were then tapped at 1425 F and checked for gas with the reduced pressure tester.

If any gas was found to be present, the degassing operation was repeated. Samples were taken from each heat for chemical analysis. After tapping, all molds were poured consecutively from the same crucible, with close temperature measurement to obtain the proper pouring temperature.

Temperature Measurement

Since pouring temperature is of such great importance in determining metal fluidity, it is necessary to measure temperatures precisely. In these experiments, a chromel-alumel thermocouple, enclosed in an iron protection tube, was immersed in the crucible at the time of pouring. Melt contamination was prevented by coating the iron tube with a layer of silica-bentonite wash. The temperature of the melt at the instant of pouring was indicated on an electronic recorder with an external cold junction (ice water).

Figure 6 presents the fluidity data obtained for the aluminum-4.5 per cent copper heats, with pouring temperature as the only variable. Fluidity increases

Fig. 4 — Cope half of single spiral pattern plate.

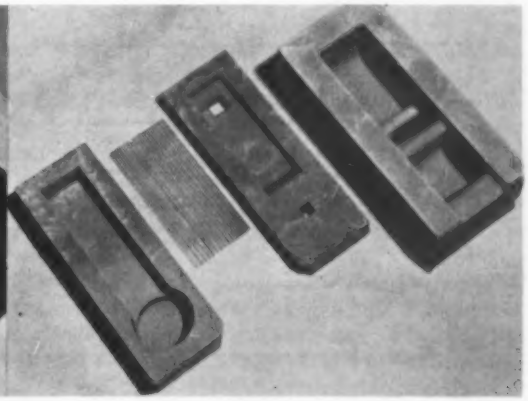

Fig. 5 — Left to right — Bottom runner core, metal screen, top runner core and pouring basin.

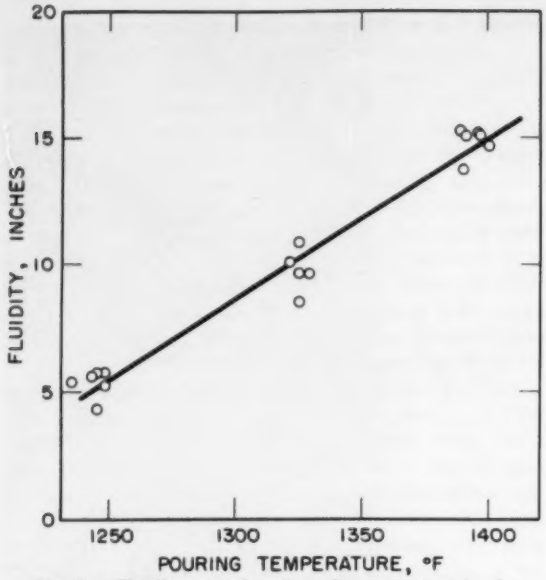

Fig. 6 — Fluidity as a function of temperature in the single spiral fluidity test (showing reproducibility of test) for Al-4.5 per cent Cu alloy. Data from three separate heats.

from about 6 in. for castings poured at 1250 F to about 15 in. for those poured at 1400 F.

Fluidity of aluminum-copper alloys containing from 0 to 20 per cent copper is shown in Fig. 7. Length of flow depends markedly on copper content as well as on superheat. Up to about 1 per cent copper, fluidity decreases with increasing alloy additions; further alloying increases fluidity. For alloys poured at constant superheat, increasing copper contents (above 1 per cent) increase fluidity only slightly. However, for alloys poured at constant temperature, the improvement in fluidity with increasing alloy addition is much more pronounced.

Figure 7 clearly illustrates that both the composition of an alloy and its superheat are important in determining fluidity of the alloy. Composition (alloy analysis) affects the mode of solidification in the flowing stream, and superheat affects the rate of solidification at critical locations in the stream.[24]

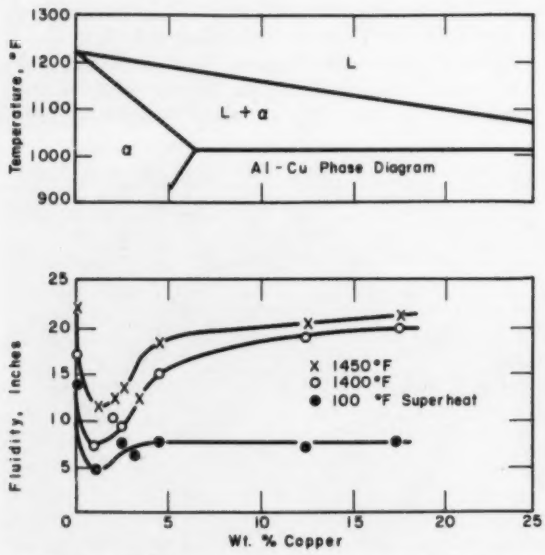

Fig. 7 — Fluidity vs. composition for the aluminum copper system at various pouring temperatures.

The results obtained in the green sand mold fluidity test (Fig. 7) are in qualitative agreement with results previously obtained by Courty[21] and by Floreen and Ragone,[4] both of whom studied fluidity in the aluminum-copper binary system. As mentioned above, Courty employed a bottom pouring crucible and metal mold; Floreen and Ragone employed the "vacuum fluidity test."

Double Spiral Mold Design and Testing

During the later stages of this research program, as increased emphasis was placed on the study of mold coatings, it became evident that a test casting with two identical spirals attached to a single runner would be desirable. This arrangement would permit comparison of mold variables in a single casting. For example, in checking the effect of a particular mold coating, one spiral only would be coated and the other would serve as a reference standard. The double spiral test is shown in Fig. 8.

Essentially, the only differences between the single and double spiral designs are that in the latter two spirals are attached to the runner, and the spirals are in the drag rather than the cope. The second modification was to permit observation of metal flow in the spirals. With the spirals in the drag it is possible to embed glass "viewing plates" in the cope and follow metal flow visually or by motion picture photography. Work on this aspect is currently underway, and has provided interesting and valuable information which will be reported at a later date.

Reproducibility of this spiral was checked, as was that of the single spiral, by pouring 30 test castings of aluminum-4.5 per cent copper alloy at three different precisely determined temperatures. The results are shown in Fig. 9. A straight line has been drawn through the points for reference; the slope is the same as that of the line drawn for the single spirals, Fig. 6. Reproducibility in this test, as in the single spiral is to within about ±1 in. of flow at a given temperature.

Absolute fluidity values obtained in the double spiral were slightly lower at all temperatures than

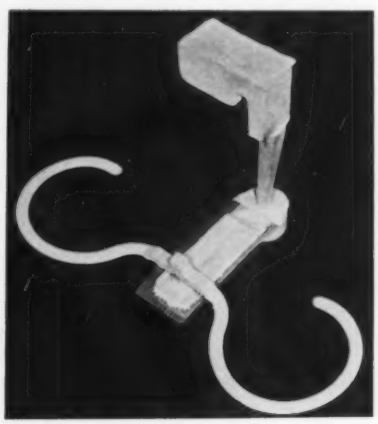

Fig. 8 — Double spiral fluidity casting with gating system.

those of the single spiral (about 1.4 in. less). Correspondence between the length of the right hand and left hand spiral in a single casting was found to be within 1 in., except for one of the 30 castings where the difference was 1.5 in.

Thicknesses of 27 spirals were measured at intervals along their length. Average thickness of all spirals was 0.123 in. with the average thickness of any one spiral deviating from this by not more than about ±0.005 in. Thus, there was no difficulty encountered in obtaining an accurate and reproducible flow-channel.

Consistent variations in thickness were, however, found in the individual spirals. All spirals measured were slightly undersize (0.001-0.003 in.) in their central locations and oversize near their tips (0.002-0.004 in.). At the tip, spirals were usually undersize due to lack of complete filling of the mold cavity. The consistent variations in thickness could not be correlated with variations in the pattern equipment, and it is felt that the variations are a result of the solidification mechanism of the alloy in the spiral.

Melting and molding practice were the same in this series of heats as in the series poured to check reproducibility in the single spiral, with the exception that aluminum-4.5 per cent copper alloy revert from previous heats was employed. The revert (remelted and pigged alloy) was used in amounts up to 80 per cent of the charge. All revert was analyzed before use to assure close control of chemical composition; runners containing the screens were discarded and not remelted.

MOLD TREATMENT EFFECTS ON FLUIDITY OF AN ALUMINUM ALLOY

Work to date on this aspect of the program has consisted of 1) selecting mold coatings or other mold treatments which might be expected to improve fluidity, 2) testing these mold treatments, and 3) interpreting observed results on the basis of thermal, chemical or physical factors. This study is not yet complete, and data contained herein should be considered a progress report of continuing research.

Melting and molding techniques employed in this phase of the study were identical to those described earlier. The double spiral was used for all quantitative work reported herein; in these cases one spiral in each mold was treated and the other left untreated to act as a control. Some of the qualitative observations reported were obtained from research using the single spiral mold.

Treating agents were sprayed or dusted on the mold, depending on the particular agent being applied. Thin pieces of sheet metal were placed at several locations near the mold cavity to be sprayed. An even coating was then applied to the mold face, and the coating thickness (on the sheet metal) measured with a micrometer. Most of the fluidity data reported are from tests employing mold coatings of 0.003 ± 0.0005 in. thick. A study is also described of the effect of varying coating thickness (of one treating agent).

Amorphous Carbon and Graphite Coatings

Many foundrymen have long felt that "blacking" a mold surface (using an oxyacetylene torch) has a beneficial effect on fluidity. However, no quantitative laboratory evaluation of this has been made. In this study, the effects on fluidity of three forms of carbon as mold coatings were examined. Carbon was applied as lamp black (from an oxyacetylene torch), as activated charcoal and as graphite.

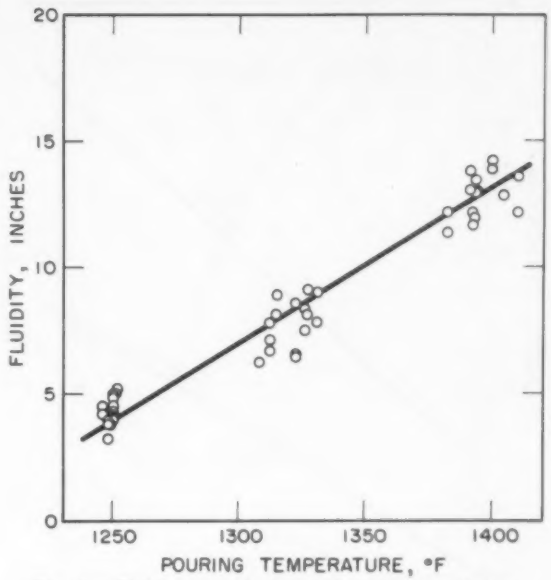

Fig. 9 — Fluidity as a function of temperature in the double spiral fluidity test (showing reproducibility of test) for Al-4.5 per cent Cu alloy. Data from seven separate heats.

Activated charcoal, in a finely divided form, was applied to the sand mold surface in controlled thicknesses by suspending the carbon particles in ether and spraying the mold. The ether volatilized quickly, leaving a uniform layer of activated charcoal particles built up to a thickness of 0.003 in. Molds coated in this manner evidenced an improvement in fluidity of about 40 per cent (i.e., the treated spiral was 1.40 times the length of the untreated control spiral).

Of greater interest are the results found by applying an amorphous carbon layer to the mold face by torching. The improvement in fluidity resulting from a 0.002-0.003 in. layer of lamp black (carbon black) applied in this manner is shown in Fig. 10. Improvement is 130 per cent at 1250 F and 68 per cent at 1400 F.

Some difficulty was experienced in attempting to obtain a uniform coating of the blacking (at 0.003 in.), due to its tendency to pile up and give unevenness; also, at thicknesses over about 0.003 in. the blacking did not adhere well to the mold surface. It would appear that if carbon black is to be used in thicknesses over about 0.002-0.003 in. it should be applied by techniques other than the use of an oxyacetylene torch.

Improvements in fluidity possible with this technique were found to be much greater than those possible with a coating of activated charcoal. Both the carbon black and the activated charcoal are amorphous forms of carbon; however, due to the extremely fine, feathery nature of the lamp black coating, its thermal insulating properties are much

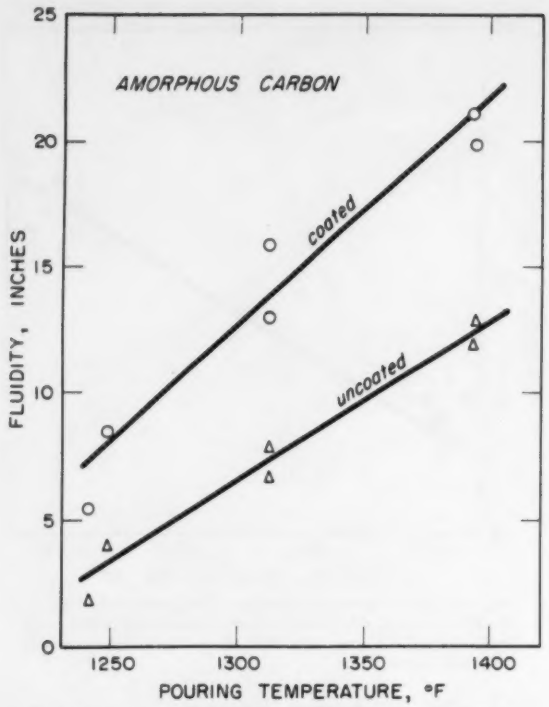

Fig. 10 — Amorphous carbon mold treatment effect on fluidity in the double spiral test for Al-4.5 per cent Cu. Mold treatment — 0.002 in. to 0.003 in. thick coating of amorphous carbon (flame application). Mold treatment was applied to one spiral in each mold; the other spiral was uncoated and was the control spiral.

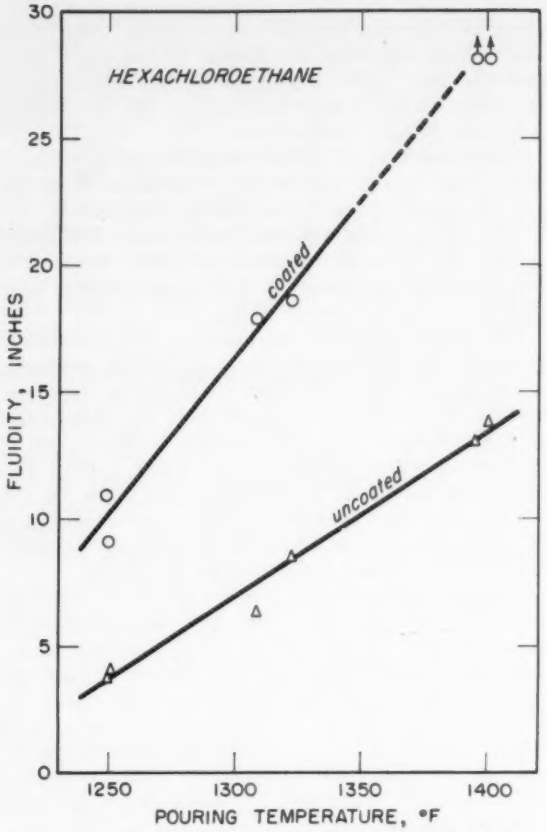

Fig. 11 — Hexachloroethane (C_2Cl_6) mold treatment on fluidity in the double spiral test for Al-4.5 per cent Cu. Mold treatment — 0.003 in. thick coating of hexachloroethane (spray application). Mold treatment applied to one spiral in each mold; other spiral uncoated for control.

greater. The thermal conductivity of lamp black is given as being more than 100 times lower than that of carbon.[25]

To complete this study, a test was made wherein spiral molds were brushed with a layer of graphite in much the same way as is done with sand molds to improve the surface finish of iron castings. No improvement in fluidity was noted in this experiment, probably because of the much higher thermal conductivity of graphite as compared to lamp black.

From these experiments it appears that the insulating qualities of the carbon coating are of primary importance in increasing fluidity. The greater the insulating qualities of a carbon coating, the greater is the fluidity increase obtained from the coating. As a check on this theory, several tests were made dusting the mold surface with a layer of gypsum ($CaSO_4$). Gypsum can be obtained in fine powder form and is highly insulating. The improvement in fluidity resulting from this treatment was substantial, and about the same as that obtained with activated charcoal.

Hexachloroethane Coating

A somewhat different approach to the problem of promoting fluidity in sand molds has been based on the use of an organic compound with a low sublimation temperature. Hexachloroethane (C_2Cl_6) has been successfully used as a spray for a mold coating. The results of the double spiral test using a 0.003 in. coating of hexachloroethane on the treated side of the mold are shown in Fig. 11. The points shown by arrows at the highest temperatures indicate that the entire length of the test spiral was completely filled (28 in.); to adequately examine the improvement in fluidity of this compound at the higher temperatures a more difficult test would be required (e.g., a spiral of a thinner cross-section or greater length).

Improvement effected by the hexachloroethane was 180 per cent at 1250 F and greater than 110 per cent at 1400 F. A series of three spiral test castings from this series is illustrated in Fig. 12.

The improvement in fluidity resulting from the hexachloroethane coating is a strong function of coating thickness, as shown in Fig. 13. A 0.003 in. thick coating improves fluidity roughly 100 per cent, while a coating 0.006 in. thick results in a 200 per cent improvement (at the pouring temperature studied). A 200 per cent improvement is equivalent to tripling fluidity, and even greater improvements with thicker coatings seem feasible. The straight line giving results for the untreated molds simply shows the consistent length of the companion control pieces on the double spiral; the coating thickness on these is constant at zero.

At a coating thickness greater than about 0.003 in. (of hexachloroethane), depressions begin to appear on the fluidity spiral castings. These depressions are not present in the absence of the hexachloroethane, and appear to be simple gas "blows." In subsequent

work using hexachloroethane to improve fluidity in plate-type castings, the gas depressions did not appear.

Mold coatings of hexachloroethane were obtained by dissolving the compound in ether to its maximum solubility and spraying the solution on the mold. The ether evaporated leaving a white coating of the hexachloroethane; no difficulty was experienced obtaining a uniform and adherent coating.

It is of interest to note here that, while the thickness of uncoated spirals averaged 0.123 in., and the thickness of the spirals coated with carbon-black averaged slightly less, the thickness of the spirals coated with hexachloroethane averaged 0.014 in. thicker (0.137 in.). Several factors may account for this. The hexachloroethane coating should be expected to separate the cope and drag at the parting line by the coating thickness (0.003 in. on each half for most runs).

Then, since the coating in the cavity volatilizes, the casting would be expected to be at least 0.006 in. thicker. Another reason may also be that the hexachloroethane permits the metal to fill the cavity more completely, through some change in the surface tension properties of the metal and/or its surroundings.

Mechanism of Improvement Due to Mold Coatings

The improvements in fluidity resulting from amorphous carbon and gypsum coatings have been attributed to the insulating qualities of these compounds. These coatings do not seem likely to affect the surface characteristics of the flowing metal or to enter into any other important metal-mold reaction. Complete proof that the insulating quality of these coatings is the primary factor has not yet been obtained; nonetheless, substantiating evidence is found in the fact that crystalline graphite has little or no effect on fluidity. Crystalline graphite is chemically identical to amorphous carbon, but has relatively high thermal conductivity.

The reason or reasons for the marked effect of

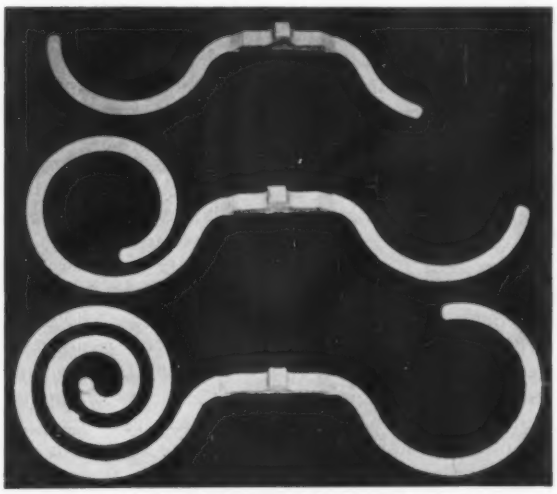

Fig. 12— Double spiral fluidity test castings showing improvement in fluidity due to C_2Cl_6 for Al-4.5 per cent Cu. Left side coated; right side uncoated. Pouring temperature (top to bottom) — 1250 F, 1322 F and 1395 F.

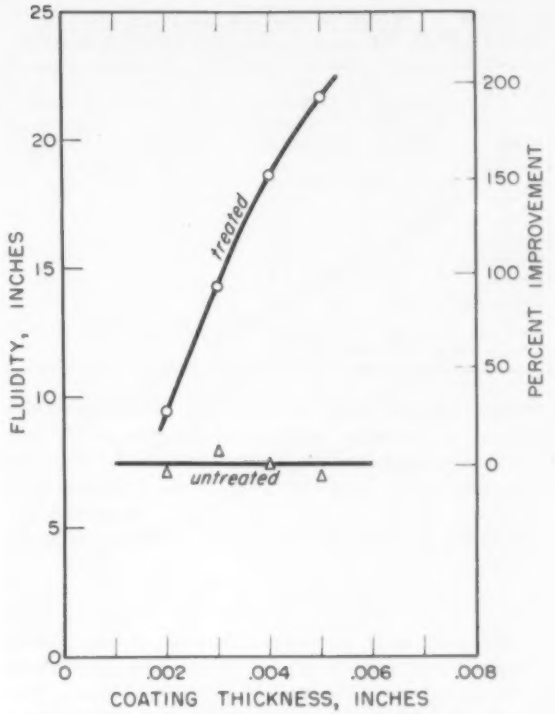

Fig. 13 — Coating thickness effect on fluidity in the double spiral test for Al-4.5 per cent Cu. Mold treatment — hexachloroethane (spray application). Pouring temperature — 1330-1305 F. Mold treatment applied to one spiral in each mold; the other spiral uncoated for control purposes.

hexachloroethane on fluidity is not immediately evident. Hexachloroethane is a chlorinated hydrocarbon of composition C_2Cl_6 which sublimes at 560 F (293 C). Possibilities which might account for its effect on fluidity include:

1) *Chemical reaction involving alteration of the aluminum oxide skin at the top of the flowing stream.* A typical reaction would be,

$$Al_2O_3 + 3Cl_2 = Al_2Cl_6 + 3/2\,O_2, \text{ at } 1200\ F$$

From available thermodynamic data, the standard free energy of this reaction is an extremely large, positive number,[5] and it is evident the reaction as written will not proceed to any appreciable extent. It is known, however, that chlorine has some physical or chemical effect on aluminum oxide, since chlorine so effectively fluxes aluminum oxide from molten aluminum.

An experiment was made by allowing concentrated chlorine gas to flow through the mold cavity until its presence was noted by emergence of the greenish-brown gas from the sprue. Results seemed to indicate that no simple reaction between the chlorine released by the decomposition of the hexachloroethane and the metal is responsible for the beneficial effects of the compound. Improvement in fluidity resulting from the chlorine treatment was small and not greater than that obtained when a similar experiment was conducted using nitrogen.

2) *Variation of heat transfer conditions between the*

TABLE 1 — VARIOUS MOLD COATINGS EFFECTS ON FLUIDITY OF ALUMINUM-4.5% COPPER ALLOY*

Mold Coating	Fluidity Control Spiral, in.	Fluidity Coated Spiral, in.	Fluidity Increase due to coating, in.	Increase due to coating, %
$ZnCO_3$	8.2	15.1	6.9	85
$CaCO_3$	7.7	14.1	6.4	84
NH_4Cl	8.3	8.9	—	—
NH_4BF_4	8.5	7.3	—	—
NH_4NO_3	7.8	7.9	—	—
$(NH_4)_2CO_3$	7.6	6.8	—	—

*Coatings were applied approximately 0.003 in. thick. Pouring temperatures were 1340-1295 F.

metal and the mold material. It is possible a partial layer of gas at the mold-metal interface could conceivably limit the rate of heat transfer between the molten metal and the mold wall. The increased fluidity in the molds coated with amorphous carbon has been attributed to just such an insulating effect.

3) *Displacement of oxygen by decomposition products of the hexachloroethane.* As an upper limit this could alter the surface tension of the flowing metal from that of aluminum oxide to pure aluminum, or even to that of some aluminum compound exhibiting lower surface tension than pure aluminum.

More detailed discussion and mathematical analysis of the possible importance of the preceding factors are given in the original report on which this paper is based.[5] Results are not, however, conclusive; and it is hoped that analytical and experimental studies now being conducted in the M.I.T. Foundry Laboratory will more clearly delineate the action of hexachloroethane in improving metal fluidity; and that other expedients for enhancing fluidity of molten metals may be found on the basis of the theory developed.

Other Mold Treatments Effects on Fluidity

Several tests were made to study the effect of skin drying on fluidity. Spirals were moderately and heavily skin dried (while retaining the green sand control spiral intact). No improvement was found as a result of the drying.

It will be recalled that throughout most of this study the hexachloroethane has been applied from an ether solution. To determine if the ether itself might have some effect on fluidity, several double molds were sprayed on one side with pure ether. No improvement in fluidity resulted. Other tests have shown that the hexachloroethane improves fluidity whether applied from an ether or alcohol solution, dusted as a dry powder over the mold face or used as a sand additive in facing material.

At the present time, compounds are being selected for further testing if their chemical or physical properties are such that they might affect 1) heat transfer conditions, 2) surface tension of the flowing metal, or 3) surface oxide films of the flowing metal.

Another phase of the study of factors affecting fluid flow of molten metals being given serious consideration is possible alteration of surface tension and oxide forming properties by additives to the metal.

TABLE 2 — HEXACHLOROETHANE EFFECT ON FLUIDITY OF SOME COMMERCIAL ALLOYS AND PURE ALUMINUM (IN THE DOUBLE SPIRAL TEST)*

Alloy	Pouring Temp., F	Fluidity Control Spiral, in.	Fluidity Coated Spiral, in.	Fluidity Increase Due to Coating	Percent Increase Due to Coating
195	1395	13.0	>28.0	—	—
Al-4.5 Cu	1318	6.3	17.9	11.6	184
	1249	3.8	11.0	7.2	190
356	1351	15.5	22.1	6.6	43
Al-7 Si-	1318	11.9	22.1	10.2	86
0.3 Mg	1246	7.2	14.1	6.9	96
220	1372	17.1	>28.0	—	—
Al-10 Mg	1312	10.7	22.9	12.2	114
	1252	10.3	16.5	6.2	60
40E	1350	8.2	13.2	5.0	61
Al-5 Zn-	1299	7.2	13.2	6.0	83
0.5 Mg-	1248	4.0	6.6	2.6	65
0.5 Cr					
99.9 Al	1396	18.7	>28	—	—
	1318	13.8	20.4	6.6	46
	1240	9.9	16.9	7.0	71

*Symbol (>) used when metal ran complete length of fluidity spiral (28 in.). These represent minimum values.

Table 1 lists some representative compounds thus far examined. Zinc carbonate and calcium carbonate effect significant improvements in fluidity; both compounds evolve CO_2 gas at fairly low temperatures which presumably acts as an insulating layer. None of the ammonium compounds tested (and listed in Table 1) have increased fluidity significantly. Most of these compounds are quite hygroscopic, and may even decrease fluidity due to excessive moisture migration to the mold cavity.

FLUIDITY OF SOME COMMERCIAL ALLOYS

Hexachloroethane Effect on Fluidity of These Alloys

The green sand mold fluidity spiral provides a rapid and efficient means for determining the relative fluidities of commercial casting alloys, and for appraising the effects of mold coatings on fluidity. Table 2 and Figs. 14 and 15 summarize results of such studies on five different commercial alloys. The limited number of alloys examined were chosen to be as representative as possible of the wide range of alloys which are ordinarily sand cast. Alloys chosen were pure aluminum (99.9 per cent), 356 alloy (A1-7 per cent Si), 195 alloy (A1-4.5 per cent Cu) and 40E alloy (Al-5 per cent Zn-0.5 per cent Mg-0.5 per cent Cr). Alloys 356 and 195 were of high purity.

In Fig. 14 relative fluidities of the five alloys are plotted versus pouring temperature (no mold coating). The pure metal is seen to be most fluid, and the aluminum-zinc-magnesium alloy least fluid. Data in Fig. 14 agree generally with practical experience in commercial foundries. In Fig. 15, the same data are plotted versus superheat temperature (above the liquidus). This type of presentation clearly indicates the important effect of mode of solidification on fluidity; at constant superheat the pure metal is much more fluid than commercial foundry alloys.

Hexachloroethane mold castings improved fluidity of all the alloys tested (Table 2). The degree of improvement obtained varied from about 43 per cent to 190 per cent depending on the alloy and pouring temperature. All data in this study were for coatings 0.003 in. thick.

Mold Coating Effect on Fluidity in Thin Plate Castings

In some earlier fluidity investigations, data from cast spirals have been found to correlate with actual foundry experiences, while in other studies the correlation has been poor. To assure that results in this investigation would apply to practice, results were checked using a simulated production type casting.

The test casting chosen, shown in Fig. 16, consisted of two ⅛-in. plates, 10 in. wide by 12 in. long. The plates were placed on opposite sides of a large runner and filled from a single tapered spiral. The pouring basin employed was the same as the one used for the spiral castings. Advantages of this design are 1) the extensive thin section plate closely represents actual thin section production castings desired in aircraft and missile fabrication, and 2) the double plate arrangement permits coating one cavity and leaving the other uncoated as a control.

Figures 16 and 17 illustrate the effect of hexachloroethane on fluidity of two aluminum alloys poured into flat plate castings; a fluidity spiral was poured with the plate casting shown in Fig. 17. The casting of Fig. 16 is for 195 alloy and for Fig. 17, 356 alloy. The same tests were made for 220 and 40E alloys with the same striking effects. In all cases one of the plate cavities was coated with hexachloroethane, the other left uncoated. Large improvements resulting from coating the mold are clearly apparent. It has been experience to date that, in this plate casting, the coating permits reductions of pouring temperature of at least 100 to 200 F, while still filling the mold cavity.

The surface appearance of the cast plates was not affected by the mold treatment, except that in one casting poured at a low temperature, depressions from partial misruns or from gas pressure were observed. These depressions, which were often found in fluidity spirals, were entirely absent in plates cast above 1300 F. Radiographic examination of representative flat plate castings showed that the treated plates were entirely free from entrapped gas. Shrinkage was present in some cases in castings made in both the treated and untreated molds.

CONCLUSIONS

1) The green sand mold spiral fluidity tests developed in this investigation have been shown to be reproducible to within about ± 1 in. of metal flow. Slightly higher absolute values of fluidity were obtained in a single spiral design as compared to a double spiral design.
2) Fluidity of an aluminum-4.5 per cent copper alloy increases about 0.6 in. per 10 F increase in pouring temperature (in both the single and double spiral test).
3) For aluminum-copper alloys of varying copper content (0.20 per cent), alloys of approximately 1 per cent copper exhibit minimum fluidity. Fluidity data are presented for these alloys at constant pouring temperature and at constant superheat.

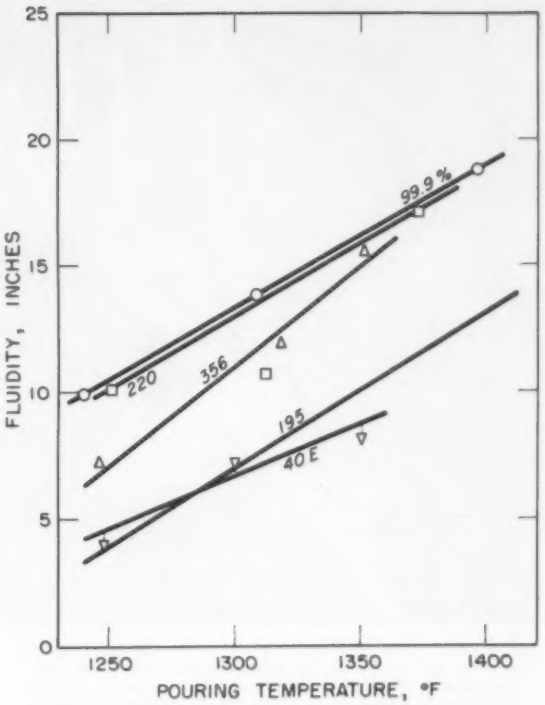

Fig. 14 — Fluidity as a function of pouring temperature of some commercial casting alloys in double spiral test. Data for 195 alloy taken from Fig. 9.

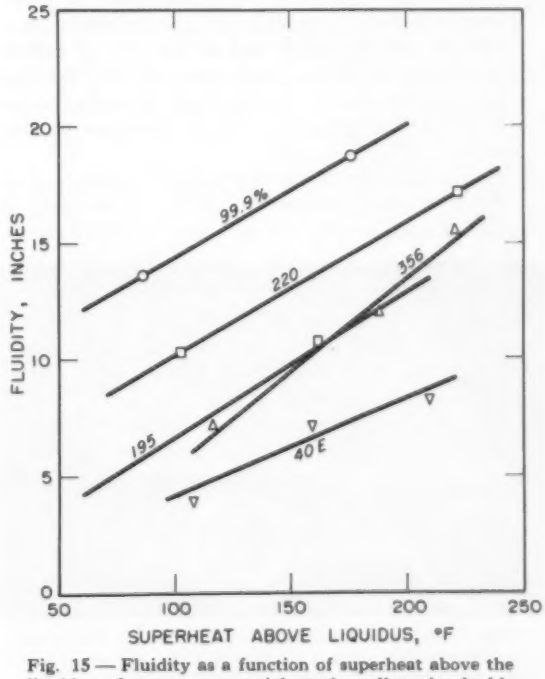

Fig. 15 — Fluidity as a function of superheat above the liquidus of some commercial casting alloys in double spiral test. Data for 195 alloy taken from Fig. 9.

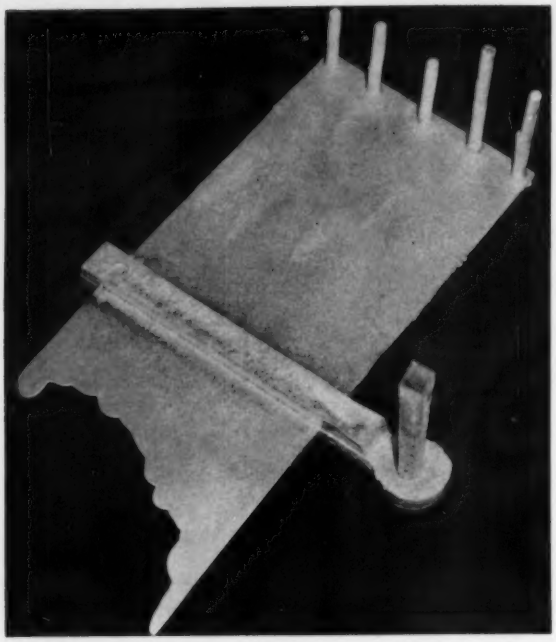

Fig. 16 — Test casting to determine effect of mold treatments on fluidity in plate-like sections. Test casting shown illustrates improvement effected by hexachloroethane treatment on fluidity of 195 alloy. Casting consists of central runner system feeding two identical plates (one on either side) 10 x 12 x ⅛ in. thick. In molding, 5 vent holes ½-in. in diameter are cut at the extremity of each plate. Alloy — 195 (Al-4.5 per cent Cu). Mold treatment — right side coated with 0.003 in. thickness of hexachloroethane, left side uncoated. Pouring temperature — 1400 F.

4) Amorphous carbon mold castings (in a thickness of 0.002-0.003 in., applied by a smoking oxyacetylene torch) improved the fluidity of an aluminum-4.5 per cent copper alloy. Improvement was 130 per cent at 1250 F and 68 per cent at 1400 F.
5) A coating of finely powdered activated charcoal was less effective than torch blacking and a coating of crystalline graphite did not improve fluidity at all.
6) Hexachloroethane mold coatings approximately 0.003 in. thick increased fluidity 190 per cent at 1250 F and at least 120 per cent at 1400 F.

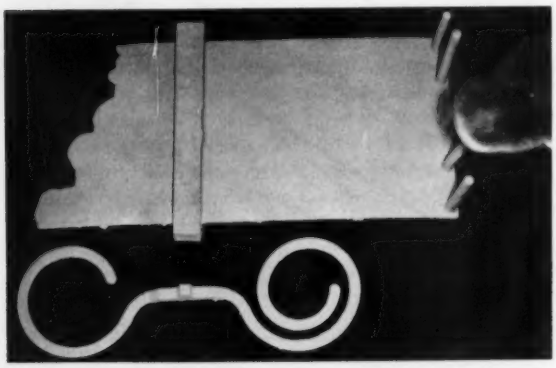

Fig. 17 — Hexachloroethane mold treatment effect on fluidity of 356 alloy. Left side of spiral and plate uncoated; right side coated with 0.003 in. layer of hexachloroethane. Pouring temperature — 1350 F.

7) Improvement in fluidity resulting from hexachloroethane mold coatings was a direct function of coating thickness. At a thickness of 0.006 in., fluidity of aluminum-4.5 per cent copper alloy was approximately tripled (at 1330-1305 F).
8) Improvements in fluidity resulting from other mold coatings (including $CaSO_4$, $ZnCO_3$ and $CaCO_3$) were noted. Insulating properties of the coatings are thought to be important in increasing fluidity but other factors may also contribute. For example, certain of the coatings may alter the surface tension or surface oxide films of the flowing metal.
9) Fluidities of five aluminum alloys were measured in the double spiral test. These were pure aluminum (99.9 per cent), 220 alloy (Al-10 per cent Mg), 356 alloy (Al-7 per cent Si-0.3 per cent Mg, high purity), 195 alloy (Al-4.5 per cent Cu, high purity) and 40E alloy (Al-5 per cent Zn-0.5 per cent Mg-0.5 per cent Cr). Fluidities of the alloys decreased in the order listed.
10) Hexachloroethane mold coatings resulted in substantial improvements in fluidity of all alloys listed above.
11) A flat plate casting was designed to test the effect of mold coatings on fluidity in a simulated production casting. Large increases in fluidity were obtained with hexachloroethane coatings. In the case of aluminum-4.5 per cent copper alloy a 0.003 in. thick coating permitted filling the plate at approximately 1300 F pouring temperature. In the absence of the coating the cavity did not fill completely at 1450 F.

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PATTERN ENGINEERING MATERIALS

new horizons

By J. Edward Olson

ABSTRACT

A new rubber-like plastic pattern material was tested to see if it would withstand the pressures and abrasion of normal molding operations. The results of these tests are given. Disadvantages of this material are also reported.

INTRODUCTION

The word *horizon* is defined as the bounds of observation or experience. The title implies that there has been an extension of these bounds so that we may anticipate, or realize, an extension in the life of pattern equipment.

The need for new pattern materials is evidenced by the high initial cost, short life and continuing high cost of maintenance and repair of present high production patterns. One need only look at the rapid growth of the die casting and plastics industry to realize that foundrymen must reduce costs in order to maintain their position in the present competitive market.

Pattern cost is reflected in casting cost, therefore, most foundrymen would like to have patterns that are low in cost and high in life expectancy. The initial cost of original or master pattern equipment will probably maintain its present cost relationship. This reasoning indicates that the immediate problem is to find materials that will substantially increase pattern life and reduce maintenance costs.

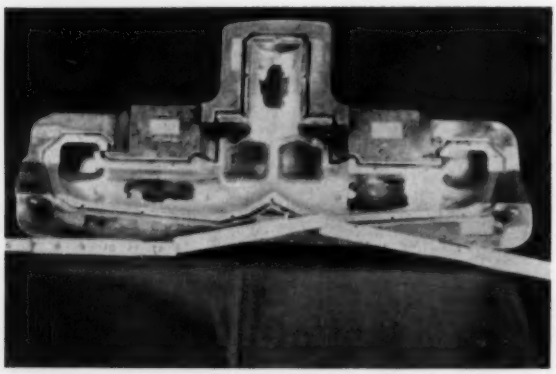

Fig. 1 — Fast plastic repair made under blow tube areas in core box.

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Using the cause and effect analytical approach indicates that more progress has been made in treating the effect than eliminating the cause of poor pattern life. The nature of foundry molding operations such as jolt, squeeze, ram, blow, sling and vibrate contribute to the wearing away of pattern equipment. Since the immediate future does not indicate any radical change in molding technique, the solution to the problem will probably be found in:

a) Development of a better method of repairing existing pattern equipment.

b) Development of a pattern material that will last longer than existing materials.

NEW PRODUCTS

Problem A

An investigation into (a) indicated conventional materials such as plastic wood, epoxy putties, brazing, welding and soldering left much to be desired. This dissatisfaction, and the search for improvement, resulted in the development of a new product.

With this new material, repairs can be made rapidly by use of a plastic compound that cures in a short time. A hardener powder is mixed with the plastic compound and spread on the repair area. Depending on the amount of hardener powder used, the material sets in 5 to 10 min to a hard, dense repair. After hardening, the material may be sanded, milled, drilled, tapped, filled and chiseled without injury or dulling of tools. The finish will accept conventional pattern coatings such as shellac or lacquer, and can be used effectively without coatings.

The compound contains additives that have good slip characteristics which aid in drawing the core or pattern. Other areas of use include increasing fillet size, adding draft and finish and making fast pattern changes. The low cost of the material, the speed with which it can be used, the good wearing characteristics and the reduction in repair time indicate this type of material meets the requirement set forth in (a) (Fig. 1).

Problem B

The approach to the problems in (b) included a review of conventional pattern materials (wood, aluminum, magnesium, iron, steel, phenolics, epoxies,

foamed plastics and masonite). While sand blast tests indicated some materials were more abrasion resistant than others, all the materials fell short of the long life requirements. Patterns made from polyvinyl chloride plastic were evaluated and rejected due to the hardening effect of kerosene and parting agent sprays. Rubber patterns were tested, and while they were highly abrasion resistant there was too much deformation when the rubber was of the ideal hardness to resist abrasion. Also, when the rubber was hard enough to resist deformation the abrasion resistant characteristics were lost.

Other known plastics also were evaluated, and finally one material was selected. This was a rubber-like plastic material having the physical characteristics given in Table 1.

Chemical Characteristics

Resistance to kerosene and fuel oils of this material is excellent. Acids, alkalis and highly reacted chemicals (such as methylene chloride, benzene, carbon tetrachloride, toluene and alcohol) will either destroy the material or cause severe swelling. Although water absorption is almost negligible, there is a possibility of slight swelling in water or in high humidity atmospheres.

TEST PROCEDURES

Abrasion Resistance Tests

The test equipment used was a laboratory type of sand blast unit, a gravity fed sand supply feeding a sand blast gun and an air line pressure of 100 psi. Comparative tests were made with the standard materials mentioned previously, with the results showing that the plastic rubber lasts from 3 to 5 times longer than the other materials tested.

Additional tests of severe conditions not normally experienced in the molding process showed good results. A nozzle was made of the plastic rubber and placed in a grit blast unit. After $\frac{1}{8}$-hr of continuous blasting, the nozzle was removed and measured. The inside diameter of the original hole measured $\frac{5}{16}$-in. After the test, the hole had increased to $\frac{3}{8}$-in., indicating a wear of $\frac{1}{32}$-in. on a side.

In another test a section of the material was held directly under the discharge end of a sandslinger. No wear effect was observed.

Impact Resistance

Under the best of conditions pattern equipment may be damaged due to improper handling. The resulting dents, scratches, cracks or marks become transferred to the mold and finally into the casting.

Using a 2 lb ball peen hammer, a $\frac{1}{2}$-in. thick piece of plastic rubber was given repeated blows up to the physical limits of the person using the hammer. Close inspection of the product indicated no damaging effects.

File Test

Using an 8 in. bastard file, a 1 in. diameter rod of the material was tested with the file held in the flat position. Under normal pressures, there was no apparent stock removal after repeated filing. However, by using the sharp edge of the file, it is possible to penetrate the material.

TABLE 1 — PHYSICAL AND CHEMICAL PROPERTIES RANGE, SOLID PLASTIC-RUBBER ELASTOMERS

Abrasion resistance	exceptional
Tensile strength, psi	4000 to 6500
Elong. at break, %	400 to 600
Tear strength, psi	300 to 750
Compression modulus at 10% deflection, psi	100 to 1000
Hardness, shore A	60 to 98
Modulus of elasticity, psi	at 300%, 600 to 3000
Compression set resistance	good to outstanding
Heat resistance	to 250 F, continuous duty to 350 F, intermittent duty
Specific gravity	1.24

Molding Tests

The first molding tests involved the use of tubular plastic rubber measuring 3 in. inside diameter, $3\frac{1}{2}$ in. outside diameter and 3 in. long.

Test A. Conventional core sand was hand rammed into the tube. After filling the tube it was rapped lightly, and although there was no draft in this piece the plastic rubber drew perfectly. No release agent was used, yet there was no evidence of sand adhering to the inside diameter of the plastic rubber mold.

Test B was a repetition of test A, with the exception that CO_2 sand was used. The green core was drawn without rapping. The draw was perfect, and there was no evidence of sticking. The second part of this test was similar, but this time the core was gassed in the mold. Again, the draw was perfect and there was no evidence of sticking.

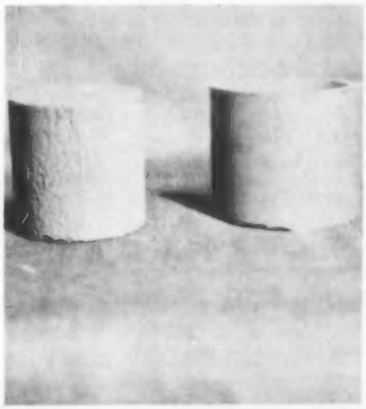


Fig. 2 — Preliminary molding tests in CO_2, core sand and green sand.

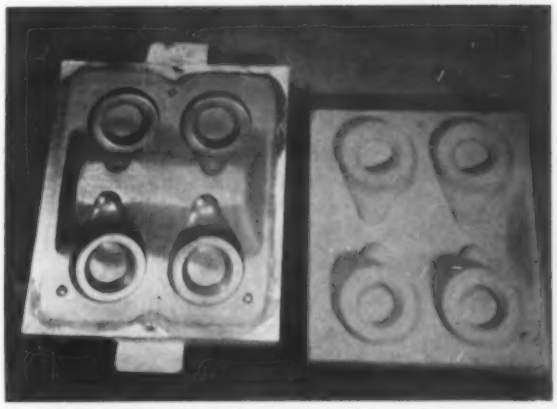


Fig. 3 — Further molding tests in CO_2, core sand and green sand.

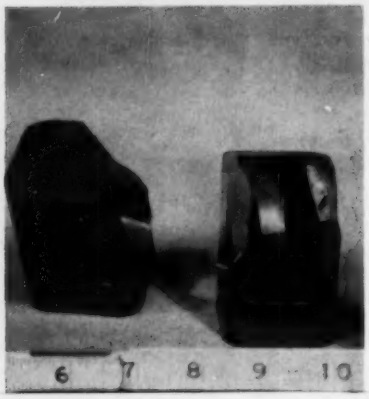


Fig. 4a (above) and 4b (left) — Molding automotive cores with plastic rubber inserts.

Test C involved the use of standard green sand, as used in a gray iron foundry. Sand was rammed in the mold, rapped slightly and drawn. Again, a perfect draw resulted, and no evidence of sand sticking in the mold. The mold used, and the resultant core, are shown in Fig. 2.

Test D involved the use of a pattern which simulated a matchplate. The base of this matchplate was made of cast aluminum which had been coped out allowing a ⅛-in. space between the coped out area and the master. Plastic rubber had been molded and bonded to this matchplate which affected a continuous surface ⅛-in. thick.

The molding test on this unit first involved the use of CO_2 sand (Fig. 3). A frame which simulated a flask was set around the pattern, the mold was filled, rammed, struck off and drawn. The draw was as it was for the previous tests, and there was no apparent sticking of the CO_2 sand. Additional molds were made under the same conditions with equal results.

This same mold was taken on a jolt squeeze machine using conventional green sand. The mold was filled, jolted and squeezed. After roll over and draw it was noted that there was some sticking sand. By spraying a standard parting agent, sticking was overcome. A serendipity effect was realized in that the mold hardness was increased approximately 20 per cent by using this plastic rubber mold as compared to an aluminum matchplate. This hardener ram condition was due to the alternating deformation of the plastic rubber during the jolt and squeeze operations.

This same mold was taken under a standard sand-slinger and molds were made. It was observed that the molds were much harder than normal. The pattern drew perfectly, and there was no evidence of sand sticking.

Test E involved the use of plastic rubber inserts in an automotive cylinder head, water jacket core box. The conventional method involved the use of cast iron inserts which were unsatisfactory due to their

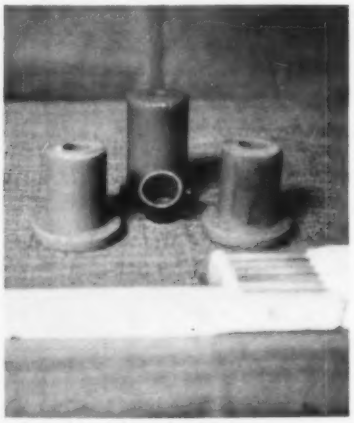


Fig. 6 — Core box blow tubes in plastic rubber.

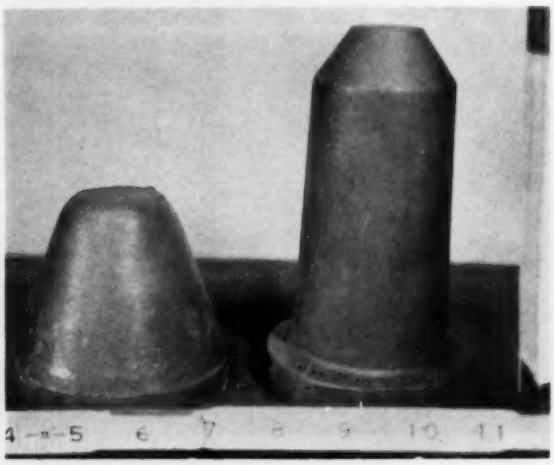


Fig. 5 — Molding feeder — risers.

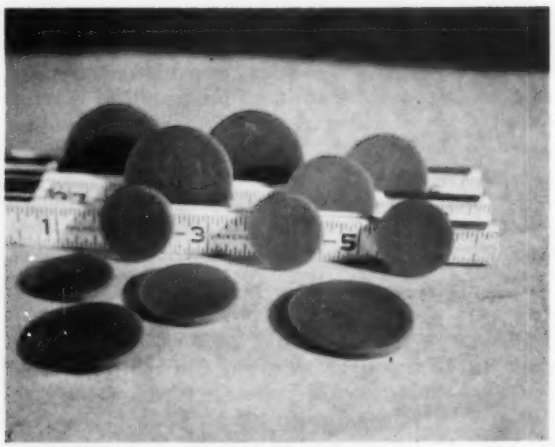


Fig. 7 — Reducing wear under the blow tubes with plastic rubber inserts.

poor abrasion resistance. This type of insert showed wear after only 500 core blowing cycles. Plastic rubber inserts were made forming the core for the area immediately above the combustion chamber. While not conclusive, the tests as of this date indicate that the plastic rubber is lasting longer than the cast iron, as illustrated in Figs. 4a and 4b.

Test F involved the use of a plastic rubber part to form riser-feeder mold cavities in the jolt squeeze molding process, as shown in Fig. 5.

This process was accomplished by filling and jolting the mold. Steel forms or patterns the shape of the feeder-riser were attached to the squeezer head. As the mold was squeezed the feeder pockets were formed. This type of molding technique resulted in heavy abrasion at the lead edge of the forming pattern (called a terracing or snow plough effect). Understandably, the life of the steel parts was short.

This same part was then made in plastic rubber, and while the results are not conclusive indications are that the plastic rubber will outlast the steel.

Pilot Pin Problem

Another problem eliminated was in a pilot pin used to guide the feeder pattern during the squeeze operation. The grinding action of the sand between the hole in the feeder pattern and the steel pilot pin cause rapid wear to the hole and pin. This resulted in a fin in the mold at the bottom of the feeder cavity which resulted in sand inclusions or improper feeding action. The use of plastic rubber eliminated this due to its wiping action on the pilot pin.

Another effect of the use of this rubber in the above mentioned instance was that during the squeeze operation the plastic rubber pattern was permitted to bottom and slightly deform. As the pressure was relieved on the squeeze operation it returned to its original shape thereby giving clearance during the draw and effecting a hard ram in the mold.

Test G. Based on the results obtained in the grit blast test, tests were begun to determine the efficiency of the plastic rubber as a blow tube material. This application is pictured in Fig. 6.

A production test lasting five weeks on a two-shift basis showed no wear to the blow tube after 34,000 blows. The only physical change noted was in the length of the tube which had increased 1 32-in. This did not present a problem as the excess was removed by grinding and the tube returned to productive use.

Test H. The area receiving the severest wear other than the blow tube is probably that directly under the blow tube (Fig. 7). Inserts of plastic rubber were made approximately ¼-in. thick and cemented using a special adhesive in the affected area. Thicker inserts for contoured areas were also made. The contours may be ground using high-speed hand-held grinding tools. Long life and stick-free operation are indicated by preliminary tests.

Test I. Previous work was done using synthetic rubber-like materials to eliminate wear at the flask bearing surface on matchplates, cope and drags and flasks. Stray sand particles lying under the flask bearing surface are an excellent abrasive medium during the jolt and squeeze operations. With the conventional aluminum to steel contact, and in the presence of sand during the jolt squeeze operation, the action is so severe as to cause deep grooves in the match or cope and drag plate and eventual destruction of the flask bearing surface.

Although synthetic rubber has done a satisfactory job in increasing the life of patterns and flasks, indications are that plastic rubber will further increase life expectancy. Figures 8a and 8b illustrate this application.

Adhesives

One of the major problems encountered in the tests was the development of a suitable adhesive for binding the plastic rubber to metal. This problem has been overcome, and a suitable adhesive has been developed which is economical and simple to use.

DISADVANTAGES

While the preceding tests are not conclusive, indications are sufficient to warrant an accelerated program of high production testing. Such a program is now under way in all of the areas mentioned.

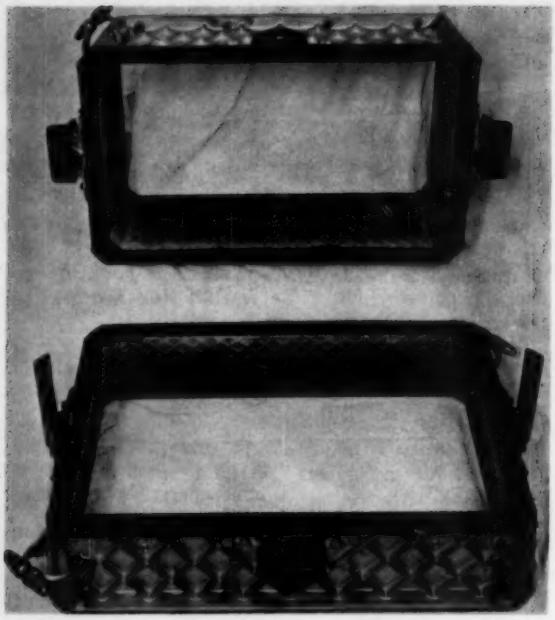
The main disadvantage of plastic rubber rests in the hands of the fabricator of the raw plastic rubber material. The handling of some of the additives is hazardous. Some of the materials are volatile and are conducive to producing allergies and/or asthmatic conditions in persons sensitive to these materials. The material is also a skin irritant, and is somewhat active on the respiratory system and mucous membranes. Extreme care must be exercised in their handling at all times. However, the hazard can be reduced measurably by the use of adequate ventilation.

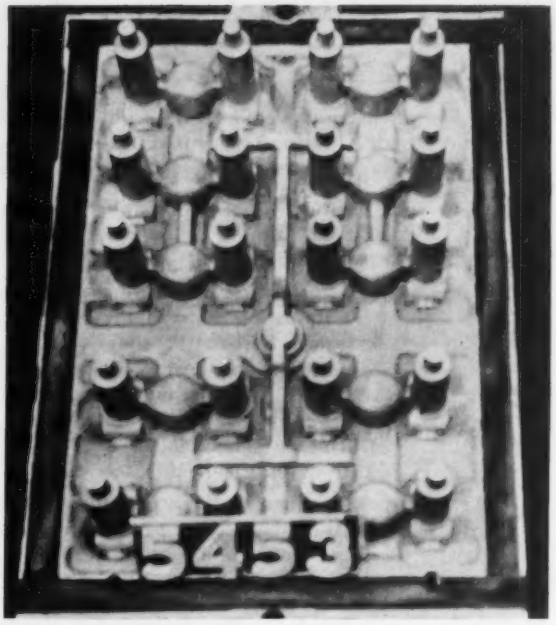
The method and the materials demand extreme care in formulating and processing. The complexity of the process involves heat, vacuum, precise proportioning, close time limits and extremely fast handling when the batch is ready. Wrong mold temperature or an excessive amount of release agent, as well as a near miss in any of the mentioned areas, will result in scrap parts. Changes in relative humidity can also have a negative effect on the quality of the end product.

While these problems seem somewhat insurmountable at times, work in the area of simplification holds promise for the future.

Shrink and Growth

In addition to the above disadvantages, there is one major area that will seriously affect the use of plastic rubber as a pattern material. This is the problem of shrink and growth of the cured product. Changes in formulation, mass and configuration can make problems in shrinkage and growth. Because of this and the other reasons previously mentioned, it is suggested that the initial studies and evaluations by pattern shops and foundries be performed by an experienced fabricator of plastic rubber. Such a service, which might be compared to that of a matchplate manufacturer, is available.





Figs. 8a and 8b — Application on the flask bearing surface (only required on one surface).

CONCLUSIONS

While the above tests are not conclusive, they were sufficiently successful to indicate that plastic rubber has a definite future as a pattern engineering material. Test results seem to indicate that reductions in repair and maintenance costs may be achieved by its use.

NOTE: The uses of plastic rubber as described in this paper or in the uses as: patterns, core boxes, inserts, blow tubes, vents, flasks, blow plates and wear strips, are covered by patents applied for and pending.

T&RI Gives Basic Course in Gray Iron Metallurgy

■ Basic principles of gray iron metallurgy were presented in detail May 25-27 in a course sponsored in Chicago by the AFS Training & Research Institute.

Attending were 25 sales representatives, engineers, metallurgists, foremen and management from eight states and the province of Ontario.

Four instructors conducted the sessions.

R. W. Heine, University of Wisconsin, Madison, Wis., outlined the iron-carbon equilibrium system, metastable iron and solidification of an iron-carbon-silicon alloy stressing graphitization and the mechanics and typical structures formed.

R. A. Clark, Electro Metallurgical Co., Cleveland, discussed the effect of chemical composition including the importance of elements, carbide stabilization, graphitizing, mechanical properties and the effect of 11 specific elements.

Harold E. Barnum, Vanadium Corp. of America, Detroit, explained the fundamentals of inoculation covering the alloys used, method and time of addition, quantity of alloy used, the effect of behavior of iron and its mechanical properties and upgrading by injection into molten iron. Barnum also spoke on the relation of carbon equivalent to mechanical properties of gray iron.

T&RI Training Supervisor R. E. Betterley discusses future courses with Harlan Bunker, Chambers, Bering, Quinlan Co., Decatur, Ill.; Donald B. Birtwistle, Great Lakes Founders & Machine Corp., Ludington, Mich.; and Thomas F. Martin, Clark Bros. Co., Olean, N.Y.

T&RI Director S. C. Massari concluded the course dealing with the improvement of gray iron through the use of alloys, section sensitivity of gray iron, effect of superheating during melting and microstructure.

Ohio Woman In Metallurgy Course

■ She's one in a thousand. Ann D. (Mrs. George T.) Needham, secretary and vice-president, Oak Hill Foundry & Machine Works, Oak Hill, Ohio, is the first woman of approximately 1000 students attending for the AFS Training & Research Institute courses. Mrs. Needham attended the Metallurgy of Gray Iron course given May 25-27 in Chicago.

Oak Hill Foundry & Machine Works, founded by her father W. E. Dole in 1901, was acquired by the Needhams in 1949. Mrs. Needham who received a Bachelor of Arts degree from Ohio Wesleyan University, has been active in foundry plant operations for 14 years. She divides her time between selling, supervision of the office and computation of cupola charges.

Said Mrs. Needham in summarizing the T&RI material, "I thoroughly enjoyed the course and I received many practical points on metallurgy and foundry control. The course makes one realize fully how little we actually know about such an extensive subject."

She is the mother of three children and has one grandchild.

Oak Hill Foundry & Machine Works includes a foundry, pattern shop, and machine shop employing 25 persons. It produces 30-35 tons of gray, white and alloy iron per week.

Mrs. **George T. Needham,** first women student in T&RI, discusses Metallurgy of Gray Iron course with instructor **R. A. Clark.**

T&RI Courses

T&RI courses offered during August and September will be found on page 114. Registration should be made with T&RI Director, AFS Headquarters, Golf & Wolf Roads, Des Plaines, Ill.

AFS 1896

news and views

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Instructors Seminar Stresses Basic

■ Success of the AFS Foundry Instructors Seminar was demonstrated by the attendance of 154 secondary school foundry and patternmaking instructors at the three-day program conducted June 18-20 at the University of Illinois, Urbana, Ill. This exceeds by 65 the previous largest registration.

Secondary instructors at the 4th Instructors Seminar, given in cooperation with the University of Illinois Division of University Extension, learned how to install, improve and better teach cast metal programs.

A look into the future was given by Prof. K. J. Trigger, University of Illinois, who discussed castings in the years to come, new materials and applications.

Much of the time was devoted to shop courses, projects and problems. *Sand in the School Foundry,* covering selection, conditioning control, additives and equipment was presented by V. M. Rowell, Harry W. Dietert Co., Detroit. *Wood Patternmaking in the School* was outlined by F. C. Cech, Max S. Hayes Trade School, Cleveland, who explained basic principles, levels of instruction, the apprentice contest and coordination with the foundry. *Ventilation in the School Foundry,* the methods, equipment, safety, meeting requirements and dangers were covered by H. J. Weber, AFS Director of Safety, Hygiene and Air Pollution. *Making a Crucible Furnace for School Use* was explained by Dr. C. G. Risher, Western Michigan University, Kalamazoo, Mich. He revealed the materials needed, methods, cost and use and operation.

Administration problems were also examined. Administrative problems in setting up school foundries were

Pouring off the heat provides spectacle to both old and novice instructors.

Society Publishes Foundry Instructors Guide

■ Valuable assistance to secondary-level foundry and pattern instructors is given in the new AFS publication FOUNDRY INSTRUCTORS GUIDE, prepared by the Industrial Arts Curriculum Committee of the AFS Educational Division.

The book is intended as a guide to those intending to install a program, those with limited equipment as well as for well-equipped departments. Teachers will find a history of the casting industry, where castings are commonly used, an operating sequence in the making of castings, recommended equipment and supplies, safe practices, how to conduct field trips and a bibliography.

Existing foundry and pattern shop layouts are illustrated with examples shown of the Milwaukee Vocational School, Milwaukee; Max S. Hayes Trade School, Cleveland; Dunbar Vocational School, Chicago; Albion High School, Albion, Mich.; and Vocational High School and Technical Institute, Minneapolis.

Casting project ideas are also presented. Forty-five pages are devoted to drawings and photographs used by secondary-level schools and universities. Plans range from paper weights to gas-fired furnaces and include layouts for vises, drill stands, a molding bench and pouring stand, city name plate, hack saw and drill press.

The book is designed for subsequent expansion and is published in loose leaf form.

Committee assignments were made in November, 1956. Dr. D. C. Williams, Ohio State University, Columbus, Ohio was committee chairman and W. P. Winter, Pennsylvania State University, University Park, Pa., was secretary. Members were M. J. Allen, American Steel Foundries, Chicago; D. A. Berg, General Motors Institute, Flint, Mich.; C. J. Freund, University of Detroit, Detroit; R. W. Haws, Ohio State University, Columbus, Ohio; Croft Merritt, Bonney-Floyd Co., Columbus, Ohio; John Pauly, Harrison Technical High School, Chicago; Carl Schaefer, Ohio State Department of Education, Columbus, Ohio; W. C. Webb, U. S. Bureau of Apprenticeship, Columbus, Ohio; Earl Strick, Erie Malleable Iron Co., Erie, Pa.

Victor Rowell explains sand testing equipment and procedures.

Melting fundamentals were shown at one workshop.

Prof. James Leach demonstrates molding operations.

Foundry Technology

analyzed by E. M. Claude, Illinois Board of Vocational Education, Springfield, Ill., who spoke on incentives, foundry work in educational programs and problems and how to resolve them. Planning and equipping a school foundry was the subject of a four-man panel. Members and their topics were: John Strange, Sterling Township High School, Sterling, Ill., *Selling the Program;* Joseph Madru, Sherman High School, Chillicothe, Ohio, *Shop Layout and Equipment;* Andrew Bottoni, Milwaukee Vocational & Adult School, Milwaukee, *Course of Instruction;* Robert Speerbrecker, Wisconsin State Department of Vocational & Adult Education, Madison, Wis., *Teaching the Program.*

Other speakers were AFS Secretary A. B. Sinnet' who explained AFS activities including technical committees, publications, the Training & Research Institute program, AFS research, education and convention and exhibits. T. H. Boardman, Division of University Extension, University of Wisconsin, told instructors of instructional aids and materials.

Workshops and demonstrations were conducted under the supervision of Prof. J. L. Leach, University of Illinois. Instructors were shown the principles of melting, molding, coremaking, CO_2 and shell molding, sand testing and wood patternmaking.

Thursday evening conferees left the university campus for dinner and inspection of the Central Foundry Div., GMC plant at Danville, Ill.

Friday evening a banquet was held at the Urbana Lincoln Hotel with the guest speaker, AFS General Manager Wm. W. Maloney, speaking on "Foundry's Challenge to Education".

The Seminar is sponsored by the Foundry Instructors Seminar Committee of the AFS Educational Division. Co-chairmen for the Seminar were Prof. R. W. Schroeder, University of Illinois, Navy Pier, Chicago and Chairman of the AFS Education Division and R. E. Betterley, AFS Educational Director.

Frank C. Cech shows secondary-school instructors patternmaking fundamentals.

High School Students Pour 32 Tons Each Year

Industrial Arts students in **Libbey High School,** Toledo, Ohio, tapping the school furnace for the city's Board of Education. Students pour 31 tons of gray iron, 1000 lb of brass and bronze and 700 lb of aluminum in each school year. Foundry Instructor **Leo Kubacki** (left) keeps up to date on foundry practice by attending the Annual Foundry Instructors Seminar. Students, left to right, are **Lloyd Williams** (Senior), **Billy Rayford** (Junior) **Bob Talamantez** (Sophomore), **Jack Eveariit** (Junior)

Conference Explains Society's Functions to Chapter Officers

■ A broad picture of AFS programs, services and future plans was presented to Chapter Officers attending the annual Chapter Officers Conference, June 11-12 at the Central Office in Des Plaines, Ill., and the Sherman Hotel, Chicago.

Attending the conference were 105 representatives from each of the Society's 47 chapters, AFS Officers, Regional Vice-Presidents and Directors.

Four special subjects received attention June 11 at the AFS Headquarters with conferees divided into four rotating groups. Each attended four, one-hour sessions where staff members explained important AFS activities. A question and answer period followed each presentation.

At session 1, AFS Technical Director S. C. Massari explained the technical functions and services; session II had AFS Education Director R. E. Betterley outlining the education program.

For session III MODERN CASTINGS Editor J. H. Schaum illustrated the handling of a typical chapter report from its receipt through printing and inclusion in the magazine. MODERN CASTINGS Advertising Manager J. M. Eckert spoke on the potential growth of the magazine and how it would benefit the Society. AFS BUYERS DIRECTORY Manager C. G. Fuller traced the steps in compiling and classifying more than 1000 product classifications and more than 30,000 product listings. The directory of approximately 400 pages will be mailed Sept. 15 to every foundry in the United States and Canada.

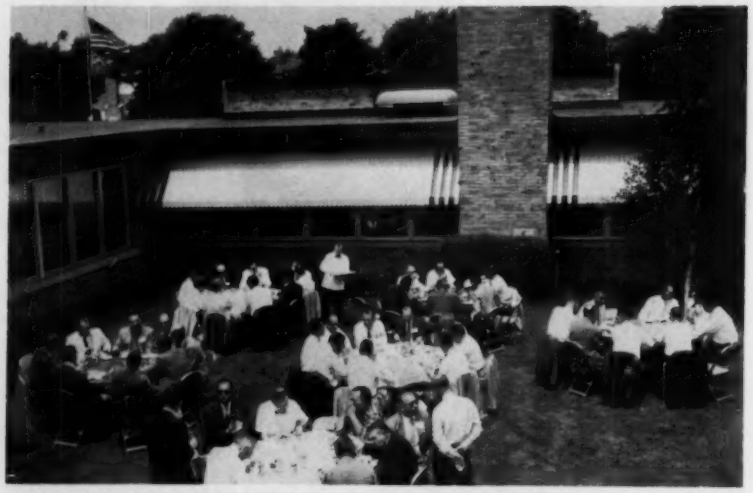
Membership activities were explained at session IV by AFS Secretary A. B. Sinnett and AFS Treasurer E. R. May. A. B. Helms, Membership Chairman, Tennessee Chapter and Frank M. Scaggs, Membership Chairman, Tri-State Chapter, explained their chapters' techniques for holding and acquiring members. Both chapters have exceeded their membership quotas.

After sessions at Des Plaines, the groups returned to the Sherman Hotel for a conference dinner. AFS President C. E. Nelson presided. Guest speaker George Gilbert Groman analyzed the speech patterns of various nationalities and geographical groups in his after-dinner talk.

Friday's program opened with a discussion of successful chapter programs by a four-man panel. Participants were Carter De Laittre, Twin City Chapter; Ted Tafel, Ontario Chapter; Roy Bossong, Canton Chapter and Don Caudron, Northern California Chapter. AFS General Manager Wm. W. Maloney and Massari summed up AFS services to chapters in planning programs.

The 1959-60 regional conference dates were reviewed by Maloney.

Canadians attending the 16th Annual Chapter Officers Conference held June 11-12 shown in front of AFS Headquarters are: **Maynard D. Bleaken,** Ontario; **Norman D. Amundsen,** British Columbia; **Leo Myrand,** Eastern Canada; **Theodore Tafel III, Robert S. Gray** and **J. W. Wallace,** Ontario; National Director **A. J. Moore; Alfred H. Lewis,** Eastern Canada; **Henry Browley,** British Columbia.



Conferees had choice of eating inside or in patio. Canadian flag was flown for the three chapter's north of the border.

S. C. Massari explains technical activities.

Open Discussions Give Time for Individual Questions

AFS Vice-President N. J. Dunbeck discussed regional administration meetings, emphasizing that Regional Vice-Presidents are "AFS Representatives" in their areas with increased responsibilities.

Other events on the morning session were: a discussion of AFS conventions and exhibits by AFS Exhibit Manager W. N. Davis and Sinnett; an outline of Safety, Hygiene and Air Pollution work by its Director H. J. Weber; advice on how to achieve good chapter administration by Maloney; and an explanation of AFS finances by Maloney and May.

Chapter Officers previewed the new AFS filmstrip *Gold Is Where You Find It* dealing with the AFS Training & Research Institute, the proposed Institute Building and T&RI objectives. Nelson and Betterley were also speakers.

The program concluded with the Shakeout devoted to answering remaining questions.

AFS Regional Vice-Presidents attended the conference with Directors and Chapter officers in their area. Regional Vice-Presidents were T. W. Curry, Region 1; W. D. Dunn, Region 2; F. J. Pfarr, Region 3; R. R. Deas, Jr., Region 4; H. M. Patton, Region 5; W. L. Kammerer, Region 6; J. N. Wessel, Region 7.

New Directors at the conference were N. N. Amrhein, R. E. Mittlesteadt, A. J. Moore, W. H. Oliver, L. J. Pedicini and J. N. Wessel. The only missing new Director was D. L. Colwell, in Europe at the time of the conference.

Other Directors were John R. Russo and Clyde A. Sanders.

Prior to the beginning of the sessions, each conferee was provided with a kit outlining the activities of the Society's departments and aids for organizing and improving chapter functions.

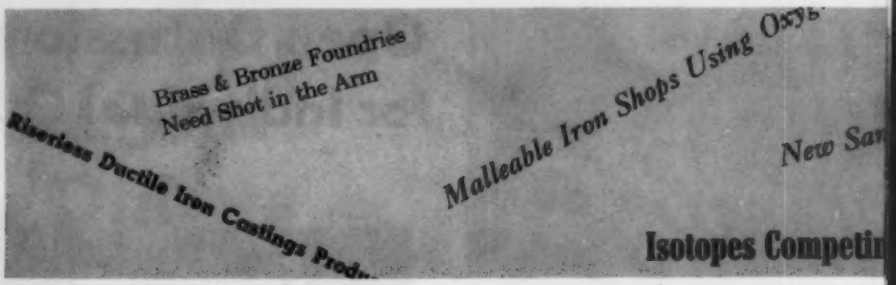
In assisting in planning chapter programs, the kits contained the AFS Speakers List for 1959-60 including an alphabetical listing of speakers and subjects, the 1959-60 Film Directory, a speakers evaluation form, hints on how to develop guest speaker data and other suggested forms.

R. E. Betterley tells of the AFS education program and assistance available to chapters.

A. B. Sinnett, AFS Secretary (standing), and **E. R. May,** AFS Treasurer, on immediate left, explained membership operations. Panelists **Frank M. Scaggs** and **A. B. Helms** told how their chapters reached their membership targets.

Jack H. Schaum, editor, MODERN CASTINGS, takes chapter officers through the steps in processing and printing a chapter report.

PENN STATE FOUNDRY CONFERENCE PENN STATE FOUNDRY CONFERENCE PENN STATE FOUNDRY CONFERENCE PENN STATE FOUNDRY CONFERENCE



Many metalcasting headlines were created during the 2d Penn State Foundry Conference which covered a broad spectrum of foundry technology. The two and a half day meeting was dedicated to the interests of the man-in-the-shop's direct responsibilities.

Some 225 men converged on the Pennsylvania State University campus June 25-27 to hear 35 speakers cover practical production aspects of gray iron, malleable iron, steel, non-ferrous alloys and sand molding. University President Eric A. Walker welcomed the conferees at the kick-off luncheon. Banquet speaker Frank G. Steinbach, vice-president Penton Publishing Co., described the magnitude and importance of the metalcasting industry.

The first day's activities were brought to a rousing

■ Gray Iron Talks

Some Factors for More Profitable Foundry Operation by **N. J. Kellner,** Westinghouse Electric Corp., Trafford, Pa. The metalcasting industry needs to keep in more direct contact with market needs to remain competitive and profitable . . . Number of gray iron foundries has declined from 3000 in 1947 to 2100 today . . . Safety program carried out by safety observers on the foundry floor . . . Good housekeeping instills pride of workmanship in men . . . Also need modernization, preventive maintenance and better communications.

Economical Founding of Ductile Iron Castings by **William Gilchrist,** The Cooper-Bessemer Corp., Mt. Vernon, Ohio. Cooper-Bessemer has realized substantial savings by producing ductile iron castings without risers. Process is made possible by . . . 1) adjusting metal composition for optimum graphite distribution to minimize metal shrinkage . . . 2) using molds of maximum rigidity rammed firmly in suitable sand within strong flasks . . . and 3) pouring rapidly through gates attached to thin sections.

Gating of Gray Iron Castings by **John F. Wallace,** Case Institute of Technology, Cleveland. Detailed parts of and relative dimensions of a good horizontal gating system were reviewed . . . Sprues, sprue wells, runners and ingates are integrated with the casting dimensions, metal fluidity and optimum pouring time . . . Graphs, nomographs and equations were presented as aids in calculating gating system dimensions.

Cupola Refractories by **Thomas E. Barlow,** Eastern Clay Products Div., International Minerals & Chemical Corp., Skokie, Ill. In patching a cupola lining above tuyeres it is best to use a concave patch which follows the contour burned out by the blast . . . Too much moisture in the patch leads to high shrinkage and cracking . . . Too little lowers patch strength . . . Lining erosion can be held down with proper tuyere design and overhang.

Use of Alloys in Gray Iron Melting by **Ralph A. Clark,** Union Carbide Metals Co., Cleveland. The relative economy of cupola charges is greatly influenced by the interplay between market price of iron in the form of scrap and the cost of addition agents containing high concentrations of silicon and manganese . . . Operating a basic or neutral cupola promotes increased carbon absorption so steel scrap becomes a practical raw material . . . Acid cupolas can boost carbon of steel charge by injecting crushed graphite into melt . . . Silicon inoculation in ladle permits melting lower silicon charge materials and makes it possible to adjust analysis to suit pouring both light and heavy castings.

■ Malleable Iron Talks

Oxgen in the Malleable Foundry by **John B. LaPota,** National Cylinder Gas, Div. of Chemetron Corp., Chicago. Oxygen is being used for enriching pulverized coal fuel in air furnaces and annealing furnaces . . . also to adjust chemistry of the iron . . . Oxygen in air furnace will . . . 1) reduce fuel consumption . . . 2) increase melting rate . . . 3) provide better control of metal bath temperature . . . 4) permit rapid selective oxidation of silicon, manganese and carbon.

Elevated Temperature Properties of Malleable Iron prepared by **L. C. Marshall** and presented by **Donald Pearson,** Link Belt Co., Indianapolis. Low carbon ferritic malleable indicates approximately 50 per cent increase in strength over high carbon ferritic at 800 F; but at 1000 F and 1200 F the two materials show no significant difference . . . Stress-rupture properties at 1000 F (3420 psi-100,000 hr) and 1200 F (1260 psi-100,000 hr) is adequate for many uses . . . Pearlitic malleable appeared superior to other unalloyed pearlitic irons and equal or superior to most alloyed irons at 1000 F (4860 psi-100,000 hr).

Pearlitic Malleable as an Engineering Material prepared by **Carl F. Joseph** and presented by **A. H. Karpicke,** Central Foundry Div., GMC, Saginaw, Mich. Pearlitic malleable iron is an engineering material that lends itself to freedom in design . . . machines 10 to 30 per cent cheaper than steel forgings . . . can be selectively flame or induction hardened . . . has hardenability equal to low alloy steel . . . exhibits good wear resistance for transmission gears and pistons . . . provides high yield strength . . . can be punched, coined and rolled. Casting quality is never an accident at Central Foundry; it results from high intentions, genuine effort, intelligent direction and skillful execution.

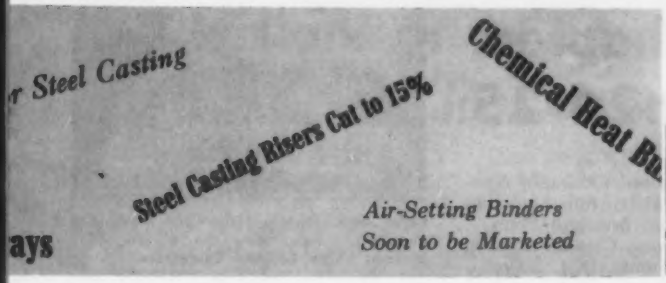
Malleable Gating and Design by **Richard E. Rosien,** Eastern Malleable Iron Co., Wilmington, Dela. Before deciding on your final gating system for a job, examine sample castings for several days . . . Often it's advisable to carry samples through anneal before accepting the gating . . . Clean castings can best be achieved by using skimmer cores, chokes, drag-cope-drag runners and wide, thin ingates . . . Correct feeding involves proper use of live risers, dead risers, chills and proper pouring temperature.

■ Non-Ferrous Talks

Looking Ahead in the Non-Ferrous Foundry Industry by **A. R. Barbour,** Roessing Bronze Co., Etna, Pa. Aluminum casting production is growing faster than the U. S. population and its general economy—probably due to excellent sales promotion by primary aluminum producers . . . With the exception of plumbing goods, brass and bronze casting production is declining severely . . . To survive, this foundry group must research new applications for its production, improve its quality and price and redouble sales effort.

Preventing Casting Defects by **Ray Cochran,** R. Lavin & Sons, Inc., Chicago. High melt quality requires . . . clean dry material . . . moisture-free furnace and ladle linings . . . short melting cycle . . . oxidizing melting atmosphere . . . minimum temperatures. Ideal gating permits . . . non-turbulent mold filling . . . no aspiration of air or gas . . . dross and slag entrapment . . . minimum erosion of mold and core surfaces.

Which Core Process in the Non-Ferrous Foundry by **Charles E. Coulter,** Archer-Daniels-Midland Co., Cleveland. Progressive foundries are using all the core processes—oil-sand, CO_2 shell,



Conferece Chairman E. J. Biller | Dr. Eric A. Walker, President Pennsylvania State Univ. | Conference Vice Chairman C. W. Mooney

conclusion with a picnic and mixer at Penn's Cave. By the end of the evening everyone was a first-class spelunker on a first-name basis.

The Conference was arranged by: Chairman E. J. Biller, Vulcan Mold & Iron Co., Latrobe, Pa.; Vice-Chairman C. W. Mooney, Link-Belt Co., Philadelphia; Secretary W. P. Winter, The Pennsylvania State University, University Park, Pa.; Treasurer H. P. Good, Textile Machine Works, Reading, Pa.; and Program Co-chairmen T. E. Eagan, Cooper-Bessemer Corp., Grove City, Pa., and H. C. Erskine, Aluminum Co. of America, Pittsburgh, Pa.

Highlights of the many excellent talks are below.

baked urea resin and air set . . . They study each job carefully and select the type of core process best suited to the situation .. . Room temperature air-setting binders and chemical curing binders are progressing rapidly to the production stage.

Engineering and the Future of Castings by **Edgar Belkin,** Westinghouse Electric Corp., East Pittsburgh, Pa. Continual improvement of casting quality level is necessary if metalcasting industry is to retain and expand its share of the market . . . This approach is necessary since designers are ever increasing the severity of operating conditions to which castings are exposed . . . The idea that casting procedures are a means of producing a cheap product but possibly inferior to other forming methods must be eliminated in favor of the realization that castings are competitive in both quality and price.

Designing for Performance; the Designer Foundry Team by **J. H. Dunn,** Aluminum Company of America, Cleveland. A check list has been prepared for designers to use in the design of cast components . . . The list is subsequently used by the foundry to indicate items influenced by foundry performance . . . If foundries provide such added services as design assistance and testing services, more business will ultimately infiltrate.

■ Steel Talks

Occurence, Production and Uses of Quality Silica by **L. G. Burwinkel, Jr.,** Pennsylvania Glass Sand Corp., Pittsburgh, Pa. Quartzite rocks are transported from our Berkeley Springs, W. Va. quarry to the world's largest silica plant. Here the rocks are reduced to original quartz grains, washed three times, dried, screened into uniform grades and vacuum cleaned . . . Silica sand is ground to flour by French flint pebbles in tube mills lined with Belgian silex blocks.

Sand Segregation by **W. D. Chadwick,** Manley Sand Co., Rockton, Ill. Sand segregation in storing and handling leads to variations in molding sand grain distribution . . . This ultimately leads to variations in casting quality . . . To minimize segregation, sand should be drawn from as many openings as possible, distributed uniformly over the complete base of the storage bins or silos.

Cold Curing Type Binders by **Frank H. Dettore,** G. E. Smith, Inc., Pittsburgh, Pa. Extensive work has produced a completely air-setting core and molding material which will require no baking . . . This new binder material is applicable to iron and steel castings weighing up to eight tons with a metal section of four inches, maximum . . . Bonded sand has good flowability, superior collapsibility, easy shakeout and produces excellent casting finish.

Moldable Exothermic Materials by **John E. Gotheridge,** Foundry Services, Inc., Cleveland. Moldable exothermic riser sleeves perform the function of a self-heating refractory with high insulating properties . . . Wide, shallow riser sleeves are best for directional solidification and for economy . . . Riser volumes for steel castings can be lowered to as small as 15 per cent . . . Exothermic heater pads in mold walls can extend riser feeding distance and permit feeding thick sections through thin.

Utility of Sand Binder 230 in Steel Foundry Molding Sands by **John L. Dewey,** Dow Chemical Co., Pittsburg, Calif. A new sand binder for steel molding sand can be used as a substitute for cereal with following benefits . . . no pH control needed . . . improved flowability . . . higher rammed density . . . more uniform green hardness . . . cleaner pattern release . . . better pattern draw . . . 90 per cent less gas . . . better collapsibility . . . good sand peel . . . cleaner, sharper casting detail.

Ferro-Alloys — Production, Uses and Future Trends by **E. R. Saunders,** Union Carbide Metals Co., Div. of Union Carbide Corp., New York. The ferro-alloy industry is engaged primarily in the reduction of metallic oxides in ores to their metallic state with highest purity commercially feasible . . . The submerged arc furnace is the principal tool used for this operation . . . New ladle additives are exothermic with chemical heat built in to offset chill effect.

Deoxidation Practice in Steel Foundries by **John N. Ludwig, Jr.,** International Nickel Co., Pittsburgh, Pa. Oxidation of molten steel bath in arc furnace must be adequate for hydrogen removal . . . Carbon deoxidation is initially applied to minimize levels of nonmetallic products of deoxidation . . . There is a logical sequence in the use of silicon, manganese, aluminum and calcium alloys to obtain maximum mechanical properties.

Isotopes in the Radiography of Steel Castings by **Mark P. Rosumny,** Picker X-Ray Corp., Waite Mfg. Div., Cleveland. Only two radioactive isotopes, Cobalt-60 and Iridium 192 have met the requirements of safety, reasonable half-life, output and energy of radiation . . . There is little difference between isotope radiography and x-ray . . . Isotopes have the advantage of economy, portability and absence of maintenance.

■ Sand School Talks

Sand Control in the Foundry by **Earl Woodliff,** consultant, Detroit. Trace elements, such as iron oxide, tannic acid, salt, silt, calcium and magnesium have strong influences on properties of molding sands . . . 0.2 per cent salt improves moisture retention of sand . . . Hydrated line is good for pH control.

Further comments on sand practices were made by five members of a panel —**H. W. Meyer,** General Steel Castings Co.; **Larson Wile,** Lynchburg Foundry Co.; **T. C. Jester,** Darling Valve & Mfg. Co.; **John Fuqua,** Cooper Alloy Corp.; and **P. W. Green,** General Electric Co.

Sand Control in the Foundry, by **George Watson,** American Brake Shoe Co., Mahwah, N. J. Trend is toward lower moisture content on molding sand . . . Moisture is source of hydrogen and oxygen found in metal . . . Many foundries are using green strength in the 15-25 psi range . . . Sand mix must have plasticity to absorb expansion under influence of hot metal . . . Add cereals and seacoal to lower expansion.

This talk was backed up by comments from a panel comprised of **E. J. Richards,** Bethlehem Steel Co.; **Albert Gable,** Meadville Malleable Iron Co.; **F. T. Richards,** Oil Well Supply Co.; and **W. S. Hodge,** W. S. Hodge Foundry, Inc.

AFS Missouri Valley Chapters Sponsor Regional Sept. 24-25

■ Simultaneous steel, iron and nonferrous technical sessions will be conducted at the Missouri Regional Conference to be held Sept. 24-25 at Rolla, Mo.

Sponsors are the AFS St. Louis, Tri-State, Mo-Kan Chapters, the University of Missouri School of Mines and Metallurgy Student Chapter and the University of Missouri School of Mines and Metallurgy.

The Conference will be held in the school's Parker Hall. Dan A. Mitchell, Progressive Brass Mfg. Co., Tulsa, Okla., is the Conference Chairman.

Luncheons will be held both days and a jamboree and barbecue is scheduled for Thursday evening.

THURSDAY, SEPT. 24

Morning Sessions

8:00 am—Registration, Parker Hall.

10:00 am—Conference Opening, Auditorium, Parker Hall. Presiding: Dan A. Mitchell, Progressive Brass Mfg. Co., Tulsa, Okla., Conference Chairman.

10:15 am—Address of Welcome, Dean Curtis L. Wilson, Missouri School of Mines and Metallurgy, Rolla, Mo. Response, AFS Regional Vice-President Webb L. Kammerer, Midvale Mining & Mfg. Co., St. Louis.

10:30 am—General Sessions.

Presiding: Charles Ossenfort, Fairbanks Morse & Co., Kansas City, Kans.

Facts About the Training & Research Institute and New American Foundrymen's Society Developments, AFS General Manager, Wm. W. Maloney.

What the Customer Expects from Foundries, Howard A. Williams, Eaton Mfg. Co., Cleveland.

12:15 pm—Luncheon, Lutheran Church. Presiding: Conference Chairman Dan A. Mitchell.

Speaker: A. Carl Weber, Laclede Steel Co., St. Louis.

Afternoon Sessions

Steel

Presiding: Vernon Lich, General Steel Castings Corp., Granite City, Ill.

2:10 pm—*Cast Steel, Last Word in Engineering Material,* Jules Henry, Missouri Steel Castings Co., Joplin, Mo.

3:15 pm—*Dielectric Core Baking,* Mitchell B. Milonski, American Steel Foundries, Granite City, Ill.

Iron

Presiding: John O'Meara, Banner Iron Works, St. Louis.

2:10 pm—*Fundamentals of Cast Iron Metallurgy,* William H. Moore, Meehanite Metal Corp., New Rochelle, N. Y.

3:15 pm—*Sand Practice in the Iron Foundry,* Joseph Schumacher, Hill & Griffith Co., Cincinnati.

Non-Ferrous

Presiding: Presiding officer to be announced.

2:10 pm—*Melting and Fluxing of Non-Ferrous Metal,* Harry Ahl, Malleable Iron Fittings Co., Branford, Conn.

3:15 pm—*Aluminum Castings—Defects and Their Corrections,* D. L. LaVelle, American Smelting & Refining Co., South Plainfield, N. J.

5:30 pm—Ozark Jamboree & Barbecue, Forest Springs Lodge, Newburg, Mo.

FRIDAY, SEPT. 25

Morning Sessions

Steel

Presiding: F. H. Hohn, Scullin Steel Co., Div. Universal Marion Corp., St. Louis.

9:10 am—*Can a Market Be Produced?,* George K. Dreher, Steel Founders' Society of America, Cleveland.

10:15 am—*Can Bentonite Be Evaluated?,* Arthur Zrimsek, Magnet Cove Barium Corp., Des Plaines, Ill.

Iron

Presiding: R. W. Trimble, Bethlehem Steel Co., Tulsa, Okla.

9:10 am—*Gating and Risering of Iron Castings,* Charles Walton, Gray Iron Founders' Society, Cleveland.

10:15 am—*Fundamentals of Cupola Practice,* Walter R. Jaeschke, Whiting Corp., Harvey, Ill.

Non-Ferrous

Presiding: Presiding officer to be announced.

9:10 am—*Melting and Casting of Aluminum Bronzes,* J. D. Dick, Montreal Bronze Ltd., Montreal, Que., Canada.

10:15 am – *Permanent Molding – Static and Centrifugal,* N. A. Birch, American Brake Shoe Co., National Bearing Div., St. Louis.

12:15 pm—Luncheon, Lutheran Church. Presiding: Conference Chairman Dan A. Mitchell.

Roar of the Crowd, Harry H. Kessler, Sorbo-Mat Process Engineers, St. Louis.

Afternoon Sessions

Steel

Presiding: E. O'Brien, Oklahoma Steel Castings Co., Tulsa, Okla.

2:10 pm—*Eight Interesting Stories of Material Handling and Maintenance* at General Steel Castings, Vernon Lich, General Steel Castings Corp., Granite City, Ill.

3:15 pm—*What is a Cereal Binder?,* C. F. Lourich, Corn Products Sales Co., Chicago.

Iron

Presiding: Edward G. Smythe, Tower Grove Foundry, St. Louis.

2:10 pm—*Cold Setting Cores for Iron Castings,* Daniel R. Chester, Archer-Daniels-Midland Co., Cleveland.

3:15 pm—*Shell Cores for Iron Castings,* Earl W. Jahn Shell Process, Inc.

Parker Hall, Missouri School of Mines and Metallurgy, Rolla, Mo., site of the 1959 **Missouri Valley Regional Conference.**

Non-Ferrous

Presiding: J. G. Winget, Reda Pump Co., Bartlesville, Okla.

2:10 pm—*Non-Ferrous Castings—Defects and Corrections,* Ray Cochran, R. Lavin & Sons, Chicago.

3:15 pm—*Almost Every Foundry Can Have Improved Sands,* E. E. Woodliff, Foundry Sand Service Engineering Co., Detroit.

4:30 pm—Adjournment of all sessions.

Lunsford and Vorhees Head Purdue Conference

■ Dallas Lunsford, Perfect Circle Co., Hagerstown, Ind., is general chairman of the Purdue Metals Castings Conference to be held Oct. 29-30 at Purdue University, Lafayette, Ind.

Howard Vorhees, manufacturers agent, Mishawaka, Ind., is the conference program chairman. The conference is sponsored by the AFS Central Indiana and Michiana Chapters and Purdue University.

Ohio Regional Features Simultaneous Sessions

■ Simultaneous sessions in gray iron, non-ferrous, steel and malleable will be conducted at the Ohio Regional Foundry Conference to be held Oct. 22-23 at the Deshler Hilton Hotel, Columbus, Ohio.

D. D. Krause, Gray Iron Research Institute, Columbus, Ohio is chairman of the conference sponsored by the AFS Canton, Central Ohio, Cincinnati, Northwestern Ohio and Toledo Chapters. The general conference committee consists of the general chairman and chapter chairman from the five Ohio chapters.

Merwin, Watson Head Empire Conference

■ Don J. Merwin, Oriskany Malleable Iron Co., Orinskany, N.Y., is chairman of the Empire State Regional Foundry Conference to be held Oct. 1-2 at N. Y. R. P. Watson, Chicago Pneumatic Tool Co., Utica, N. Y. is program chairman for the conference.

15 Divisions and Committees to Participate in Congress

■ Fifteen AFS Technical Divisions and General Interest Committees will participate in the 64th AFS Castings Congress & Foundry Show to be held May 9-13 at Philadelphia. The tentative program calls for 38 technical sessions, six shop courses, ten luncheons, four dinners, a nonferrous symposium in addition to meetings on AFS activities.

The divisions and general interest committees and the number of technical sessions are: Sand Division (5); Gray Iron Division (4); Malleable Division (3); Pattern Division (3); Steel Division (3); Die Casting & Permanent Mold Division (3); Ductile Iron Division (3); Fundamental Papers Committee(3); Light Metals Division (2); Brass & Bronze Division (2); Industrial Engineering & Cost Committee (2); Heat Transfer Committee (2); Safety, Hygiene & Air Pollution Control Committee (1); Education Committee (1); Plant & Plant Equipment Committee (1).

Four divisions will conduct shop courses; both the Malleable and Gray Iron Divisions will each hold two with the Sand Division and Ductile Iron Division each holding one.

Dinners include the Sand Division Dinner, Canadian Dinner, AFS Annual Banquet and Alumni Dinner.

Luncheons will be held by the Light Metals, Malleable, Brass & Bronze, Pattern, Die Casting & Permanent Mold and Steel Divisions with the Ductile and Gray Iron Divisions jointly sponsoring a luncheon. Others will be given by the Management Development Committee, AFS Board of Directors and Past Presidents.

AFS Publications Committee met in June to review the publications program and plan future progress. AFS General Manager **Wm. W. Maloney** goes over agenda with **T. E. Barlow,** Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill., **H. H. Wilder,** Vanadium Corp. of America, Chicago. Others are AFS Technical Director **S. C. Massari; T. T. Lloyd,** Albion Malleable Iron Co., Albion, Mich.; **F. C. Bennett,** Dow Chemical Co., Midland, Mich.

Committee Work Open to Members

■ Would you like to serve on an AFS technical committee? Over 600 members are now donating their time to further the work of more than 100 active committees.

Service on a national committee aids the Society through the exchange of knowledge, assists the individual by improving his knowledge and abilities and benefits employers and local chapters by keeping them posted on the latest developments.

What are the requirements? Only a willingness to attend meetings and contribute information. Any member is eligible and is invited to volunteer his services through the AFS Central Office or the chairman of a specific committee.

Technical activities are carried on by ten specific divisions in addition to general interest committees.

Technical Divisions:
- Brass & Bronze
- Die Casting & Permanent Mold
- Ductile Iron
- Education
- Gray Iron
- Light Metals
- Malleable Iron
- Patternmaking
- Sand
- Steel

General Interest Committees:
- Cast Metals Handbook Revision
- Cupola Advisory
- Fundamental Papers
- Heat Transfer
- Management Development
- Plant & Plant Equipment
- Plaster Mold Casting
- Refractories
- Safety, Hygiene & Air Pollution Control

TENTATIVE SCHEDULE OF TECHNICAL SESSIONS

64th AFS CASTINGS CONGRESS & FOUNDRY SHOW — May 9-13, 1960

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
7:30 am	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast
9:30 to 11:30 am	Light Metals Malleable Pattern	Brass & Bronze Pattern Malleable SH&AP T&RI Trustees	Annual Business Meeting & Hoyt Lecture	Steel Ductile Iron Fundamental Papers Die Casting & Perm. Mold	Sand Heat Transfer Ductile Iron Fundamental Papers
12:00 Noon	Light Met. Luncheon Malleable Luncheon	Brass & Bronze Lunch. Pattern Luncheon Board of Directors Luncheon & Meeting	Management Lunch. Die Casting & Perm. Mold R. T. Luncheon	Steel Luncheon Ductile & G. I. Lunch. Past Presidents Lunch.	
2:00 to 4:00 pm	Pattern Non-Ferrous Symposium (2:00-5:30 pm)	Light Metals Education Ind. Engrg. & Cost Gray Iron	Steel Die Casting & Perm. Mold Gray Iron Plant & Plant Equipment	Heat Transfer Ductile Iron Fund. Papers	
4:00 to 5:30 pm	Sand	Sand Light Metals Gray Iron Malleable Brass & Bronze	Ind. Engrg. & Cost Die Casting & Perm. Mold Sand	Steel Gray Iron Sand	
6:00 pm		Canadian Dinner Sand Dinner	Annual Banquet	Alumni Dinner	
8:00 to 10:00 pm	Sand Shop Courses Mall. Shop Courses	Mall. Shop Course Gray Iron Shop Course		Gray Iron Shop Course Ductile Iron Shop Course	

Watch . . . your molding sand

by Ray Cochran
R. Lavin & Sons, Inc.
Chicago

This talk relates some experiences on scrap problems caused by or alleged to be caused by molding sand.

Our foundry produces castings for Chevrolet only. Rated capacity is 3200 tons per day. Record tonnage in 18 hours is 3674 tons. We have 22 molding units plus a floor operation for casting equipment parts and patterns for machining. Molding sand is prepared in two ways. In the older foundry section, shakeout sand, spill sand and conveyor sand additions are jointly fed into an elevator from the basement below each molding unit and raised to a separating screen high over the molding unit.

The sand falls through a screen to a pug mill where water is added. From the pug mill the sand passes through the aerator to the storage bin. A belt then transports sand to an elevator which discharges it onto the sand distribution belt running over the molding machines.

I am sure you have all been plagued with chimneying caused by slugs of dry sand and wet sand in the storage hopper. You have all seen or used wood mallets to get the sand moving to the bars. To solve the problem we set air jets on the side of the hopper. Periodically these jets are activated and a tremendous improvement in the movement of the sand through the storage hopper results.

In the newer foundry section, shakeout sand, spill sand and bonding sand additions are fed to a holding hopper and then to a mixer located at floor level. We have been experimenting with reversing the end blades of the mixer to hold the sand back and get a better mixing action. On one installation to date we have achieved an actual 25 per cent reduction in clay costs.

In visiting with various foundrymen it seems that the majority of scrap problems common to foundries are scabs, drop outs, mold blows, burn in, dirty castings, pin holes and inclusions. Finally, there is one which verges on all of the above but which we prefer to set up as a separate category--just plain carelessness.

Scabs—Scabs on established jobs are generally related to sand. If you have made no radical changes in the mix and you begin to get scabs, then lower your moisture, reduce the fines in the sand and check on the seacoal or other cushion content of the sand. We do not recommend a change in the sand mix. We do recommend a checkup to see if you are on specifications. Meanwhile, check that ramming. Also check the gating where scabbing has been and continues to be a source of difficulty.

Drop Outs—Drop outs are generally mechanical—for instance, poor ramming, plugged squeeze boards, double squeezing. On the machinery side check for rebound on jolting and sticky draw posts.

Blows or Gas—Molding sand contributes to blows by having poor permeability and by being high in seacoal or moisture. We believe that in our operation, at least, more mold blows are caused by poor iron, hard ramming, green cores, wet cores, hard cores and lack of adequate venting than can be attributed to molding sand which is out of control. Also, don't forget wet ladle lips and green ladles. Blows sometimes can be eliminated by gating for more uniform feeding. This generally occurs in round castings with flat surfaces. By narrowing the gates but doubling the number of gates, buckshot blows have been stopped.

Burn In—This one is another most generally caused by wet strong sand or voids permitting iron penetration. Would you believe it could be caused by excessive ramming of sand that was within specs. In this case our problem involved a side core that was surrounded on all but one side by the cope half of the mold. Only one face of the side core was exposed to molten iron. This fact had a tendency toward severe burn in. If the mold was over-rammed, turbulence set up in the very hard mold would not permit gas to escape. Therefore gas came out on the iron face, causing the core to spall and effect a terrific burn in.

Dirt and Inclusions—Take a quick look at your sand control reports to be sure that your moisture is not too low. Then watch everybody at his job with a very critical eye. If cores are being set, be sure the cores are clean and that the talc on the cores is smooth, not feathered in curly edges. Check your iron pourers for sloppy pouring habits such as failure to skim and losing the head of iron.

Pinhole Porosity—Certainly there are

FOUR Requirements fo

by W. C. Schartow
Chevrolet-Saginaw
Grey Iron Foundry, GMC
Saginaw, Mich.

■ The identification of defects and the application of the required cure can easily become a negative approach to the quality problem. The ultimate remedy is prevention.

A certain knowledge of metallurgical fundamentals is necessary to keep quality control from becoming a trial and error procedure. The requirements for a sound high quality casting can be grouped and discussed under four headings: 1) Melt Quality; 2) Gating; 3) Feeding; 4) Temperature.

1 High melt quality is synonymous with low gas content. Furthermore, it must be achieved without damage to the original composition. This means freedom from addition of undesirable elements as well as loss of any element originally present.

In general, high melt quality is obtained by constant surveillance of the melting operation to insure adherence to the following conditions . . . clean dry material . . . moisture-free furnace and ladle linings and tools . . . shortest possible charging and melting cycle . . . oxidizing atmosphere (0.50% O_2 in the combustion products) throughout the melting cycle . . . use of minimum operating temperatures which are consistent with the other phases of the casting operation.

2 Gating has as much influence on casting quality as melt quality. The various features of a system must be designed to perform certain specific functions. The most important single feature in a system for a brass or bronze casting is a choke. Gating ratios for such castings should contain four factors rather than the conventional three. These should be sprue, choke, runner, ingate. Using the bottom of a tapered sprue is not as satisfactory for choking as it is in

uality Casting

aluminum. Ideal gating systems accomplish these following functions . . . permit the mold to fill at an optimum rate without undue turbulence and without excessive temperatures . . . prevent aspiration of air or gas . . . minimize erosion of mold and core surfaces . . . trap dross and slag . . . promote directional freezing . . . provide maximum yield and minimum cleaning consistent with high quality.

The gating system on a pattern or matchplate must be as well mounted, fitted and finished as the pattern itself. This promotes cleanliness and reproductibility in molds.

3 Knowledge of feeding of castings requires an understanding of the way metals solidify. The pure metal which freezes without the formation of compounds at different temperatures, the short freezing range alloy which approximates this mode of freezing and the long freezing range alloy which passes through a long pasty state, all are treated differently.

These general principles of feeding must be observed . . . riser location must be determined by the directional solidification pattern . . . risers should be filled with the last metal to enter the system . . . risers must remain liquid until the entire sections affected by those particular risers have solidfied . . . if "cold risers" must be used, also use insulators, exothermics, chills or hot-tapping in conjunction with them . . . take advantage of gravity, hydrostatic pressure and atmospheric pressure.

4 All of the foregoing factors affect the last of the requirements for a sound casting—the optimum pouring temperature. There is one best temperature for any casting. Pouring a series of test bars at various temperatures proves this. The shorter the pouring range, above and below this optimum point, the better and more uniform the castings will be. Almost as much trouble arises from pouring too cold as from pouring too hot.

Editor's Note: *This article contains highlights excerpted from a talk presented at the* 1959 *AFS Southeastern Regional Foundry Conference and Texas Regional Conference.*

occasions when pinhole porosity can be attributed to sand; if the moisture or the combustibles in the sand are high enough so as to cause the blowing of gases through the molten metal there can be little question but that the sand is responsible for a pinhole condition. In our experience with green sand molding of camshafts, a job in which pinholes are occasionally encountered, we have found that a sand of higher density gives better results. We have increased the density of our sand by adding about 20 per cent bank sand in our new sand (bond) additions and increasing the clay content and the moisture content of the sand.

Summary—

1) **Make the best molding sand you can with the machinery and facilities you have available to do the job you require.**
2) **Once you have what you feel to be a good sand, stick with it. Make the necessity for changes be proven and worthwhile.**
3) **A good molding sand with proper controls will cause you very little scrap.**
4) **A lot of scrap alleged to be caused by molding sand "ain't necessarily so."**

Editor's Note: *This article contains highlights excerpted from a talk presented at the* 1958 *Michigan Regional Foundry Conference.*

DRY SAND SEGREGATION

by T. W. Seaton
American Silica Sand Co.
Ottawa, Ill.

Do you realize that dry sand segregates every time it is moved from one place to another? This is true whether moved by the teaspoonful or by the carload, and whether we move it across the table in a laboratory or several hundred miles in a railroad car.

• Segregation of sand is the reason that careful attention must be paid to sampling procedure. The effects of molding and core sands and ultimately on the castings produced in them are of great importance. Many cars of sand have been needlessly rejected because of careless sampling of this material which is so prone to segregate.

• Now let's go to the problem of storage and handling. Most sand storage piles are segregated with coarse particles to outside and finer particles toward center. Such a sand pile presents us with some interesting problems.

1) Obtaining a representative sample from this pile is extremely difficult. Thus, we cannot be absolutely certain as to its distribution and fineness.
2) If, in removing sand from this stockpile we take our sand entirely from the outside edges, we run into a sand which will be coarser than desired. As a result, metal penetration and rough castings will very probably result.
3) Once the outer portions of the pile have been removed, we begin taking sand from the central portion of the pile, which is finer than anticipated. We now have a possible low permeability problem as well as the many other problems which may develop when the sand is too fine.

• The problem is: how do we obtain a representative batch of sand for our muller from this stockpile? The best method is to cut into it as we would a pie. Endeavor to keep the ratio between the outer and inner portions as nearly equal as possible.

• To avoid this problem entirely, place the sand in storage in such a manner as to minimize the coning effect. Flattening out the sand pile by spreading it uniformly over the entire storage area will be of considerable help. The use of baffles to break the fall of the sand as it enters the storage area will also be of great benefit. Reducing the distance of the fall of the sand is also important.

• I also refer you to an article which appeared in the September, 1957 issue of MODERN CASTINGS, covering most of the problems related to sand handling and storage.

There are few if any foundrymen who can tell what effect a variation of 5 per cent on individual screens may have. The exception is when the variation occurs in the coarse or fine portions.

• Generally, samples carefully obtained at point of production are more representative than any taken afterward. Samples taken during car loading are the most representative of the sand in the car.

■ **Most producers have spent many thousands of dollars to control sand production, minimize segregation and obtain good samples. No progressive and reliable producer will knowingly ship an offgrade car of sand. We know that our staying in business depends upon the foundryman's ability to produce and sell castings of the highest quality.**

Editor's Note: *This article contains highlights excerpted from a talk presented at the* 1958 *Purdue Metal Castings Conference.*

T&RI Courses Study Problems from Design to Marketing

■ Solutions to foundry problems ranging from design to marketing will be described in four summer AFS Training & Research Institute courses to be held in Chicago.

First of the courses deals with core sand practice, including general information on types, characteristics, segregation, mixing and additions. Other major topics are types of binders; core practices with discussions on mechanical properties, additives, mixing and baking; an outline of green baked and hot core properties; the CO_2 process; the shell core process and considerable emphasis on the various causes of casting losses.

The second basic course, gating and risering of castings, includes both theory and practice starting with fundamentals and then dealing with techniques for both ferrous and nonferrous castings.

Patternmaking, the third subject, is a demonstration and lecture course dealing with wood patterns, plaster and plastic patterns, core blowing and shell mold and shell core pattern equipment.

Product developments and marketing, scheduled for Sept. 28-30 is the final summer course. It is offered in response to requests for assistance in developing and expanding markets.

East Coast Regional to Be Nov. 20-21 in New York

■ Division chairmen have been named for the East Coast Regional Conference to be held Nov. 20-21 at the Statler-Hilton Hotel, New York.

James S. Vanick, International Nickel Co., New York, is general chairman of the conference sponsored by the AFS Metropolitan, Philadelphia and Chesapeake Chapters.

J. S. Vanick

Henry Winte, Florence Pipe & Machine Co., Florence, N. J., is the conference program chairman and has charge of the gray iron and ductile iron division. William H. Baer, Army Engineers, Fort Belvoir, Va., heads the brass, bronze and aluminum division and F. B. Herlihy, American Brake Shoe Co., Mahwah, N. J., is in charge of the steel program.

1959 T&RI Courses

Aug.-Sept.

Subject and Description — *Dates*

Core Sand Practice ..... **Aug. 10-14**

Instruction covering all phases of materials, mixing and application. The advantages and disadvantages of new materials and methods are studied. Casting losses attributed to cores are analyzed for solutions. Designed for foremen, supervisors, technicians, engineers and management. Course SC1A, $90, Chicago.

Gating & Risering of Castings ..... **Aug. 24-26**

Instruction course covering theory and practice on the various problems relating to gating and risering. Metal flow, solidification phenomena, heat transfer, shrinkage, hot tears, ferro-static pressure, gate and riser design, mold wall movement and surface tension are some of the many facets covered. Intended for foremen, technicians, foundry engineers, industrial engineers and production and quality control personnel. Course GR1B, $60, Chicago.

Patternmaking ..... **Sept. 16-18**

Demonstration and instruction for patternmakers, foremen, supervisors, trainees, purchasers of castings, suppliers and management—materials, equipment, layout, allowances, construction techniques and recent trends. Emphasis placed on new materials, processes, techniques and their applications. Course PM1A, $80, Chicago.

Producting Developments & Marketing .... **Sept. 28-30**

Instruction course on product analysis from the design to the marketing of the finished product. Study will include: casting design, stress analysis, pattern selection, equipment, cleaning operations, cost analysis, casting processes, engineering properties of cast metals and sales promotion. Scheduled for all types of foundry engineers, sales engineers, technicians, supervisors, metallurgists and management. Course PDIA, $60, Chicago.

Empire Regional Set for Oct. 1-2

■ Plant visitations and seminars on sand and epoxy resin plastic patterns will be conducted on both days of the Empire State Regional Foundry Conference to be held Oct. 1-2 at Drumlin's Country Club, Syracuse, N. Y.

Don J. Merwin, Orinskany Malleable Iron Co., Orinskany, N. Y. is the conference general chairman and R. P. Watson, Chicago Pneumatic Tool Co., Utica, N. Y. is the program chairman.

The tentative program.

THURSDAY, OCT. 1

9:00 am *Registration,* Drumlin's Country Club.

9:30 am *Plant Visitations* to three foundries, both ferrous and non-ferrous operations.

1:00 pm *Opening Luncheon,* welcome by Syracuse Mayor A. A. Henninger.

2:30 pm *Epoxy Resin Pattern Seminar,* presented by staff of Tylene Plastics Co.

2:30 pm *Sand Seminar,* presented by staff of Harry W. Dietert Co.

5:00 pm *What Does the Casting Designer Expect of Foundrymen?* T. O. Kuivinen, Cooper-Bessemer Co., Mt. Vernon, Ohio.

7:00 pm *Banquet,* entertainment and speaker to be announced.

FRIDAY, OCT. 2

9:00 am *Registration,* Drumlin's Country Club.

9:30 am *Plant Visitations.*

1:00 pm *Luncheon,* speaker, J. G. Kura, Battelle Memorial Institute, Columbus, Ohio.

2:30 pm *Epoxy Resin Pattern Seminar,* presented by staff of Tylene Plastics Co.

2:30 pm *Sand Seminar,* presented by staff of Harry W. Dietert Co., speaker, Victor Rowell.

5:00 pm *General Shakeout,* questions and discussion by panel.

chapter news

Seven foundrymen associated with Allyne-Ryan Foundry Co., Cleveland, have a total of 327 years foundry experience. Back row: **Frank L. Feltes** (55years); **Walter Seelbach,** president and general manager, Superior Foundry Co. and its Allyne-Ryan Div. (49 years). Front row: **John Wachala** (45 years); **Joseph Zucco** (42 years); **Joseph Havel** (45 years); **John Zavesky** (46 years); **James Bezacinsky** (45 years).

—**Harold Wheeler.**

Tom Reynolds, General Malleable Co., Milwaukee, 1st place winner, gray iron molding contest sponsored by the Wisconsin Chapter.

—**Bob DeBroux**

Central Indiana officers and directors shown at May meeting. New officers and directors were elected May 4. Left to right: **Gene Wens, William A. Rodefeld, Arthur Lindgren, Joseph B. Essex, George Dehn, William H. Faust, William E. Boyd, William Grimes, Jack Slickman, A. R. Downey, William M. Fitzsimmons.** W. F. Boyd was elected as chairman to succeed W. H. Faust. Other officers are vice-chairman, Thomas E. Smith III; secretary, Joseph B. Essex, treasurer, Frank W. Button.

—**W. R. Patrick.**

How to work smarter, not harder, was outlined to the **Wisconsin Chapter** by Allen H. Mogensen, Work Simplification Conferences, Lake Placid, N.Y. and Sea Island, Ga.

—**Bob DeBroux**

Members of the **University of Illinois AFS Student Chapter** recently attended a combined meeting with members of the American Society of Mechanical Engineers, Society of Automotive Engineers and Industrial Engineering Society. Shown are Dean **William L. Everett,** University of Illinois College of Engineering, speaker **Frank Soderstrom,** Blaw-Knox Co., East Chicago, Ind.; Student Chapter President **Richard Bolin; Andrew J. Paul,** Caterpillar Tractor Co., Peoria, Ill., 1958-59 Chairman, AFS Central Illinois Chapter.

Floyd Jaehnert, St. Paul Vocational School patternshop graduate is the winner of the Twin City Chapter outstanding achievement award. Photo shows Jaehnert accepting award from **Robert Mulligan,** Twin City Chapter Chairman 1958-59. On right is **H. W. Teichroew,** coordinator, St. Paul Vocational School.

—**J. W. Costello**

Tennessee Chapter Holds Ladies Night

Tennessee Chapter held its 2d annual ladies night in May. New officers were installed and certificates of appreciation awarded to retiring officers and directors. V. Dewey Annikan, Indiana State Teachers College, addressed the group. Shown are **C. E. Seman,** 1959-60 Chairman; speaker **Annakin;** AFS National Director **K. L. Landgrebe** and **W. L. Austin,** Chairman 1958-59.

—H. G. Nelson

New **Pittsburgh Chapter** Officers: Director **A. M. Cadman, Jr.** A. M. Cadman Mfg. Co.; Secretary-Treasurer, **E. P. Buchanan,** Pittsburgh Coke & Chemical Co.; President, **J. D. Wilson,** Bronze Die Casting Co.; Vice-President **W. F. Hacker,** Mesta Machine Co.

—Walter Napp

Participating in June meeting of the **Ontario Chapter** were Director **R. A. Short,** McKinnon Industries, Ltd., St. Catharines, Ont., speaker **W. Hepburn,** J. T. Hepburn, Ltd., Toronto, Ont.; 1958-59 Chapter Chairman **John M. Hughes,** Stevenson & Kellogg, Ltd., Toronto, Ont.; 1959-60 Chapter Chairman **Ted Taffel III,** American-Standard Products (Canada) Ltd., Toronto, Ont.; Program Chairman **L. H. Burbage,** Otis Elevator Co., Ltd., Hamilton Ont.

—V. H. Furlong

Central New York Chapter

Automated Pouring, Molding

■ An illustrated talk on automated molding and pouring was given at the April meeting held at Cornell University, Ithaca, N. Y., by Alex H. Homberger, International Automation Corp., Ann Arbor, Mich.

Homberger discussed the development background and features of the system installed in a Swiss foundry. The speaker said that this country with its high production costs is losing its markets to other countries. Although the system is developed for large production foundries, runs as small as 150 pieces could be automated economically. —*C. W. Diehl*

How the Foundry Educational Foundation assists students and the foundry industry was explained at the May meeting of the **Oregon Chapter.** Shown are Prof. **Paul De Garmo,** chairman, Department of Engineering, University of California, Berkeley, Calif.; **E. J. Walsh,** executive director, Foundry Educational Foundation, Cleveland; **John F. Oettinger,** Electric Steel Foundry Co., Portland, Ore.

Northeastern Ohio Chapter

Conducts Recognition Night

■ Apprentices, old-timers and past chapter chairmen were honored at the May meeting. Thirteen of the chapter's 19 living former chairmen were present, including Frank G. Steinebach, L. P. Robinson, F. Ray Fleig, Henry J. Trenkamp, Howard C. Gollmar, William G. Gude, Fred J. Pfarr, now AFS Regional Vice-President, Gilbert J. Nock, Frank C. Cech, David Clark, Jr., Lewis T. Crosby, Alexander D. Barczak and E. C. Jeter. Walter L. Seelbach, past national president also attended.

Winners of the chapter's apprentice contest were awarded their prizes. Forty-two entered the local contest. Wood patternmaking—Norman Vicic, Artisan Patterns & Engineering; Douglas Petery, Cove Pattern Works; John Sabanos, Ford Motor Co. Metal patternmaking—Louis Uveges, Ford Motor Co.; S. Gregory Monoc, Ford Motor Co.; Al Yanke, Ford Motor Co. Iron molding—William Gregory, W. O. Larson Foundry Co.; Carl Linger, W. O. Larson Foundry Co.; Junior Samples, W. O. Larson Foundry Co.

Aluminum molding—Roy Sprouse, Grafton Foundry, Inc.; Donald Beemiller, Max S. Hayes Trade School; now at Superior Foundry, Inc., Martin Kral, Max S. Hayes Trade School now at Pattern Castings Co. Uveges won first place in the AFS Robert E. Memorial Apprentice Contest and Monoc and Gregory won national third prizes in their divisions.

Pattern prizes were presented by Frank Gill, Artisan Patterns & Engineering and president, Pattern Manufacturers' Group, Associated Industries of Cleveland which co-sponsored the pattern competition with Northeastern Ohio Chapter.

Molding prizes were presented by Norman Stickney, Sand Products Co., chapter second vice-president and chairman, education committee. Don Hartman, Cove Pattern Works, was in charge of apprenticeship awards.

Curtis G. Fuller, manager, AFS BUYERS DIRECTORY, discussed the directory. —*Jack C. Miske*

Central Michigan Chapter new officers, old officers and former chairmen held a meeting June 1 at the Albion Malleable Iron Co. cottage at Duck Lake, Mich., to plan for the 1959-60 technical year.

—Melvin W. Devers

chapter news

Ontario Chapter

Foundry Operation Panel

■ Four phases of foundry operation were covered at the May meeting sponsored by the chapter's education committee. Ted Skelly, American-Standard Products (Canada) Ltd., Toronto, served as moderator. A plant visit was made to the Port Hope Sanitary Mfg. Co., Port Hope, Ont.

Panel members and their subjects: *Cupola Operation*, L. H. Burbage, Otis Elevator Co., Ltd., Hamilton; *Shell Molding & Shell Cores*, L. Humphreys, A. H. Tallman Bronze Co., Ltd., Hamilton; *Sand*, A. J. Barnwell, Canadian Westinghouse Co., Ltd., Hamilton; *Gating & Risering*, E. Rempel, McCoy Foundry Co., Ltd., Hamilton. —*Vincent Furlong*

Central New York Chapter

Cupola and Operating Problems

■ *The Cupola–Coke Burner or Iron Melter* was investigated at the May meeting by Robert W. Carpenter, Hanna Furnace Corp. Subjects under discussion were grate area, coke burning rate, air flow through the cupola, types of tuyeres, size of coke, slag and air-cooled tuyeres. —*C. W. Diehl*

Ontario Chapter

Planning in the Foundry

■ While complaints have been heard about too much paperwork in foundries, W. Hepburn, J. T. Hepburn, Ltd., Toronto, Ont., at the June meeting showed how it can be used to eliminate errors and reduce costs. Hepburn showed copies of form used from quoting to finished production. —*V. H. Furlong*

San Antonio Section

Hears Talk on Patterns

■ Problems associated with patterns and shrinkage were explained at the May meeting by Bill Rieser, Glenney Pattern Works, San Antonio, Texas. The meeting, held at K. O. Steel Castings, Inc., was attended by 33 members and guests. Officers were also elected at the meeting. They are: Chairman, Bill Rieser; Vice-Chairman, Chesley May, K. O. Steel Castings, Inc.; Secretary-Treasurer, Richard Cusack, San Antonio Machine & Supply Co.

afs chapter meetings

AUGUST

British Columbia . . Aug. 8 . . Horseshoe Bay, British Columbia . . *Salmon Derby.*

Canton District . . Aug. 1 . . Brookside Country Club, Barberton, Ohio . . *Annual Picnic and Golf Party.*

Chicago . . Aug. 8 . . Nordic Hills Country Club, Route 53, Itasca, Ill. . . *Golf Outing.*

St. Louis District . . Aug. 8 . . Shady Acres Resort, St. Louis County . . *Picnic.*

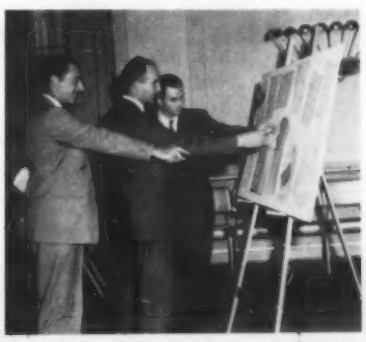
Southern California . . Aug. 8 . . Lakewood Country Club, Lakewood, Calif. . . *Summer Stag and Golf Tournament.*

Twin City . . Aug. 17 . . Midland Hills Country Club, Roseville, Minn. . . *Annual Golf Party.*

SEPTEMBER

British Columbia . . Sept. 18 . . Leon's Restaurant, Vancouver, B. C. . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

Central Michigan . . Sept. 16 . . Hart Hotel, Battle Creek, Mich.



W. Hepburn, J. T. Hepburn Ltd., Toronto, Ont., shown on right, reviews forms used to cut production costs. Others are Chapter Publicity Chairman **V. H. Furlong,** Foundry Services (Canada), Ltd., Guelph, Ont., and **John M. Hughes,** Stevenson & Kellogg, Ltd., Toronto, Ont., Chapter Chairman 1958-59.

Central Ohio . . Sept. 14 . . Seneca Hotel, Columbus, Ohio . . D. E. Krause, Gray Iron Research Institute, *"Cupola Operation."*

Chesapeake . . Sept. 23 . . Country Club, York, Pa. . . *Visitation at Cochrane Foundry, Inc., York, Pa. and Columbia Malleable Castings Corp., Columbia, Pa.*

Cincinnati District . . Sept. 14 . . Alms Hotel, Cincinnati.

Detroit . . Sept. 3 . . Wolverine Hotel, Detroit.

Metropolitan . . No Meeting.

Mexico . . Sept. 14 . . Camara Industria Transformacion, Mexico, D. F.

Mid-South . . Sept. 11 . . Claridge Hotel, Memphis, Tenn.

Northeastern Ohio . . Sept. 10 . . Tudor Arms Hotel, Cleveland . . *Ferrous Group*: F. C. Barbour, Republic Steel Corp., *"New Developments in Cupola Melting Practice"; Non-Ferrous Group*: W. E. Sicha, Aluminum Co. of America, T. D. Stay, Reynolds Metals Co. and J. J. Kroecker, Permold Co., AFS *Film "Horizontal Gating Design"; Pattern Group*: Panel Discussion, *"Casting & Pattern Design to Reduce Cost."*

Northern California . . Sept. 14 . . Spenger's Cafe, Berkeley, Calif. . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

Oregon . . Sept. 16 . . Heathman Hotel, Portland, Ore. . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

Piedmont . . Sept. 4 . . Ole Point Comfort Hotel, Newport News, Va.

Pittsburgh . . Sept. 21 . . Webster Hall Hotel, Pittsburgh, Pa. . . F. G. Steineach, Penton PUublishing Co., *"Future of the Foundry Industry."*

Quad City . . Sept. 21 . . LeClaire Hotel, Moline, Ill.

St. Louis District . . Sept. 10 . . Edmond's Restaurant, St. Louis.

Southern California . . Sept. 11 . . Rodger Young Auditorium, Los Angeles . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

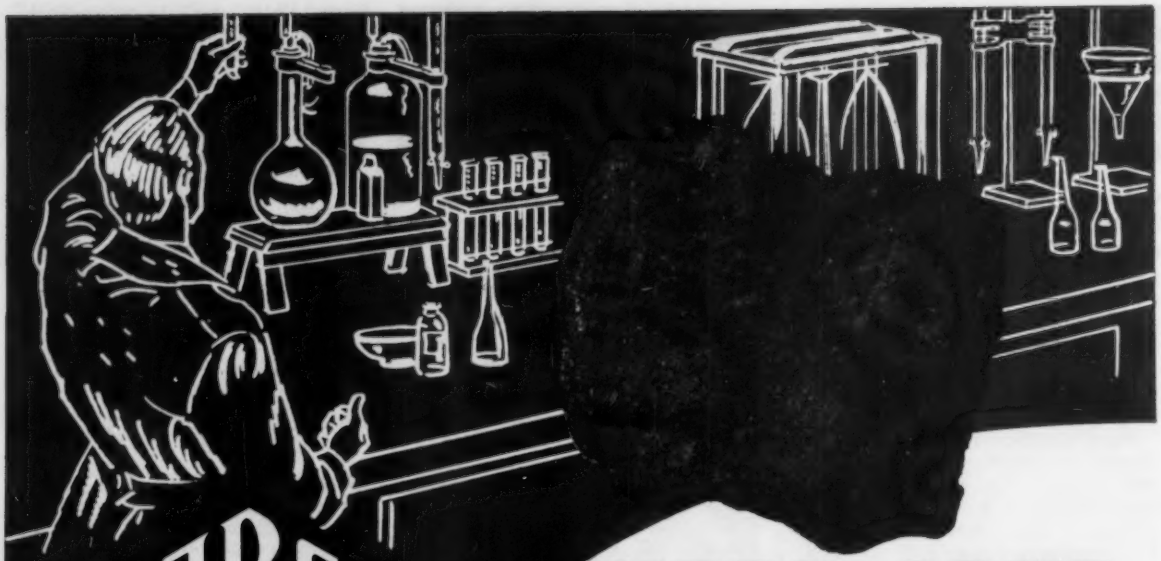
Tri-State . . Sept. 11 . . Alvin Plaza Hotel, Tulsa, Okla.

Twin City . . Sept. 15 . . Jax Cafe, Minneapolis . . J. H. Schaum, AFS, *"What's New in Metalcasting."*

Utah . . Sept. 21 . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

Washington . . Sept. 17 . . Engineers' Club, Seattle . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation in the Foundry."*

Wisconsin . . Sept. 11 . . Schroeder Hotel, Milwaukee.



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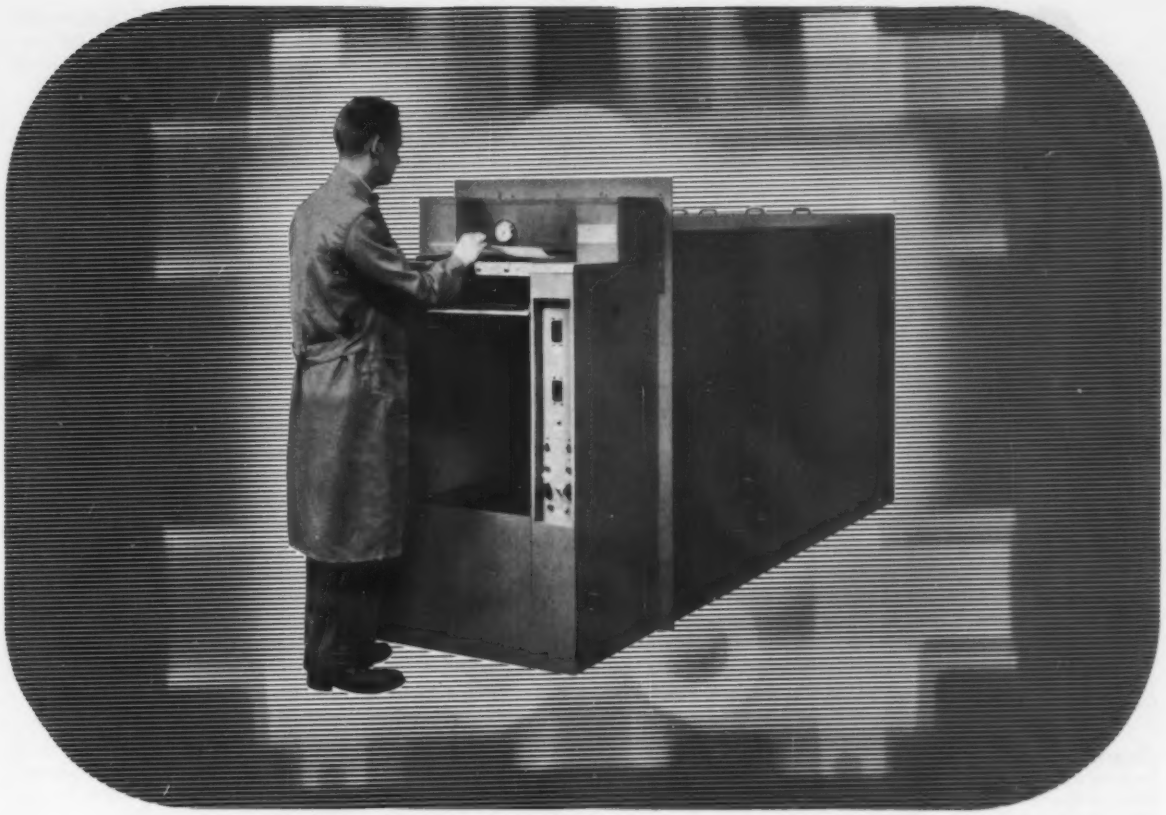

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Circle No. 164, Page 139-140

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Gating and Risering . . . refractories include strainer cores, breaker cores, gate tiles, tees and ells. Send for specification sheet 58F. *Louthan Mfg. Co.*
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High alumina mortar . . . reported to be dry, heat setting type, is new product of research. Four-page brochure tells all about it. *North American Refractories Co.*
For Your Copy, Circle No. 39, Page 139-140

Electric arc furnaces . . . and charging buckets fully described and portrayed in 50-p catalog No. 10. *Lectromelt Furnace Div., McGraw-Edison Co.*
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Charging wheelbarrows . . . single and two-wheel models covered in specification sheet. Circular No. 58. *Sterling Wheelbarrow Co.*
For Your Copy, Circle No. 41, Page 139-140

Core sand muller . . . claimed to give faster mulling job minimizing friction heat. Use the Reader Service card for folder, Form No. WL 9227. *Carver Foundry Products Co.*
For Your Copy, Circle No. 42, Page 139-140

Cherry flasks . . . designed to be easily removed are available in any length or width. Request data sheet. *Adams Co.*
For Your Copy, Circle No. 43, Page 139-140

Shell molding resins . . . are finely powdered, thermosetting synthetic resins developed for production of shell molds by the "dump-box" method. Use the number below for Technical Bulletin F-3-R. *Reichhold Chemicals, Inc.*
For Your Copy, Circle No. 44, Page 139-140

Snagging grinders . . . include combination cut-off and stand grinder. Full line covered in bulletin 259. *Fox Grinders, Inc.*
For Your Copy, Circle No. 45, Page 139-140

Steel shot performance . . . at malleable shot prices is what this company claims for its new type abrasive for blast cleaning of castings. Request data sheet. *Metal Blast, Inc.*
For Your Copy, Circle No. 46, Page 139-140

Epoxy compounds . . . are ready to use without addition of hardening agents. For technical data bulletin, use the Reader Service card, last page. *Houghton Laboratories Inc.*
For Your Copy, Circle No. 47, Page 139-140

Ductile irons . . . booklet, 28 pp, is complete with information, applications and specifications of these new cast metals. *International Nickel Co.*
For Your Copy, Circle No. 48, Page 139-140

Sigma welding . . . instructions presented in 48-p booklet. *Linde Co.*
For Your Copy, Circle No. 49, Page 139-140

Employees . . . how they can be better used to increase profits is subject of government bulletin. *Small Business Administration.*
For Your Copy, Circle No. 50, Page 139-140

Data card . . . for high temperature steels and alloys lists 19 special metals used in high temperature applications. *Allegheny Ludlum Steel Corp.*
For Your Copy, Circle No. 51, Page 139-140

Cast alloys . . . in carbon, low alloy and stainless steel groups featured on data chart including design applications of each alloy. *Lebanon Steel Foundry.*
For Your Copy, Circle No. 52, Page 139-140

Mold cavity coatings . . . colloidal dispersions said to result in more uniformly sound castings having smoother surface finishes. Send for bulletin, Vol 4, No. 1. *Acheson Colloids Co.*
For Your Copy, Circle No. 53, Page 139-140

Eliminate porosity . . . in castings. This is subject of article in company publication regarding application of lithium copper cartridges for deoxidation of molten metal. *Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries, Inc.*
For Your Copy, Circle No. 54, Page 139-140

Training courses . . . pertinent to every type of metalcasting work are offered by the AFS Training and Research Institute. For free brochure covering all courses offered, circle number below on Reader Service card, last page. *American Foundrymen's Society.*
For Your Copy, Circle No. 55, Page 139-140

Silicon . . . in cast iron discussed in 8-p brochure covering various alloys designed for addition to melting furnace. *Ohio Ferro-Alloys Corp.*
For Your Copy, Circle No. 56, Page 139-140

Lift truck attachments . . . make many foundry operations easier. Circle number below on Reader Service card, last page, for catalog No. 585. *Little Giant Products, Inc.*
For Your Copy, Circle No. 57, Page 139-140

Index . . . to 1958 Modern Castings. Lists the subjects, titles and the authors of all important information published during last year. *American Foundrymen's Society.*
For Your Copy, Circle No. 58, Page 139-140

Hiring . . . . of key executives for small plant discussed in brochure. *Small Business Administration.*
For Your Copy, Circle No. 59, Page 139-140

Investment castings . . . how to buy them is the subject of booklet outlining whether a part should be considered for this process. *Mercast Mfg. Corp.*
For Your Copy, Circle No. 60, Page 139-140

Metal castings . . . uses and advantages pointed out in question and answer form in 28-p booklet covering malleable iron, pearlitic malleable iron, gray iron, aluminum and magnesium. *Dayton Malleable Iron Co.*
For Your Copy, Circle No. 61, Page 139-140

Aluminum welding . . . training manual designed for use with inert gas process available on request. *Kaiser Aluminum & Chemical Sales, Inc.*
For Your Copy, Circle No. 62, Page 139-140

Automatic dispenser . . . for company's waterless hand cleaner shown in literature. *Quickee Products Inc.*
For Your Copy, Circle No. 63, Page 139-140

Portable, pneumatic grinders . . . a new line, detailed in data sheet available when you use the Reader Service card, last page. *Thomas C. Wilson, Inc.*
For Your Copy, Circle No. 64, Page 139-140

Meehanite castings . . . covered in 32-page booklet listing scope of applications. Also offers table of physical properties. *Meehanite Metal Corp.*
For Your Copy, Circle No. 65, Page 139-140

Flexible mask goggle . . . said to offer greater protection and better fit. Use Reader Service card, last page, for free bulletin. *American Optical Co.*
For Your Copy, Circle No. 66, Page 139-140

Depreciation . . . as an element in investment decisions is subject of address by officer of this organization. Use Reader Service card, last page, for your copy. *Machinery and Allied Products Institute.*
For Your Copy, Circle No. 67, Page 139-140

Abrasive belt . . . lubrication discussed in January issue of company publication. *Carborundum Co.*
For Your Copy, Circle No. 68, Page 139-140

Wall chart . . . depicting 10 "Do's" and 10 "Don'ts" of grinding wheel safety. *Carborundum Co.*
For Your Copy, Circle No. 69, Page 139-140

Precision castings . . . used in manufacture of radar wave guides is the subject of **tear sheet** available for the asking.

Continued on page 124

Order KOPPERS Premium Foundry Coke

Premium quality foundry coke! That's exactly what Koppers delivers car-after-car. Made from the highest quality West Virginia coals, scientifically blended and baked the right length of time, Koppers Premium Foundry Coke is absolutely *uniform* in *size, strength, structure* and *chemical analysis*. With its higher carbon content, Koppers Coke enables the foundryman to maintain a higher temperature range, thus increasing the the cleanliness of the iron. This in turn, helps reduce fuel consumption and means lower operating costs all around. Next time *order* Koppers Premium Foundry Coke. Available anywhere in the U.S. or Canada in sizes to meet your needs. Koppers Company, Inc., Pittsburgh, Pa.

WE CHECK EACH DAY'S RUN to make certain you get foundry coke of the exact size and chemistry that is most efficient for the job. Analyses are available to your foundry on request.

Circle No. 165, Page 139-140

THE VEXING PUZZLE OF THE REJECTED ROTORS

Another costly mystery solved–by the man from Kaiser Aluminum

THE PERPLEXING FACTS. A manufacturer of electric motors brought Kaiser Aluminum a perplexing problem. He was having difficulty casting sound rotors. His main problem was porosity which resulted in many rejected units.

HOW THE CASE WAS SOLVED. When the man from Kaiser Aluminum reviewed the casting process, he recommended a correction in fluxing techniques—and suggested that the casting dies be redesigned to improve gating and venting. Outcome: the porosity disappeared and the matter was closed.

WE LOVE A MYSTERY. This is one of many actual cases solved by Kaiser Aluminum working with a customer. Perhaps *you* have a mystery one of our technical engineers might help solve? He's ready to give you expert advice on any casting problem—including mold and die design, heat treatment, finishing, fluxing, metal transfer.

FULL ALLOY AVAILABILITIES. Kaiser Aluminum can supply you *fast* with a wide selection of casting alloys to suit any engineering requirement—from general purpose alloys to high purity alloys having good properties at elevated temperatures.

FOR PIG AND INGOT with a free sleuthing bonus, call your nearest Kaiser Aluminum sales office now. Or write to: Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

KAISER ALUMINUM
THE BRIGHT STAR OF METALS

See "MAVERICK" • Sunday Evenings, ABC-TV Network • Consult your local TV listing.

Circle No. 166, Page 139-140

VOLCLAY BENTONITE

..... NEWSLETTER No. 63 .....

REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

Improved Finishes With Carbon Compounds

Many foundries have learned cleaning and milling costs are directly associated with molding operation.

Poor molds produce poor castings!

Foundries have used carbon in various forms to improve finish, lubricate sand grains when rammed to retain a certain fixed carbon within the molding sand, also to promote a certain percentage of volatiles which aids peel of the casting from the molding sand.

No one carbon does all jobs required, except in rare cases.

Investigators and foundry scientists have studied this phenomena. More recently there are trends toward carbon blends.

One such investigator is W. G. Parker of the General Electric Company, Elmira, New York. Bill is a pioneer in sand technology. He has studied the effects of blending a cellulose of correct grain size with two specific carbons. One of the carbons is a more refractory graphitic type, while the third is a volatile hydro-carbon of micron size. **This blend of carbons has improved castings at Elmira foundries and consequently has saved thousands of $ $ $ $ $ $.**

Avoid unnecessary costly grinding by the use of GREEN SHELL CARB

There are other carbons which are similarly patterned. One such carbon blend is GREEN SHELL CARB. Some claim GREEN SHELL CARB sands produce closer tolerances and better finish than does shell molding. **The trend toward carbon blends is growing.**

Additional data on GREEN SHELL CARB available on request

AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • PRODUCERS OF VOLCLAY AND PANTHER CREEK BENTONITE

WHEELABRATOR® STEEL SHOT

cuts abrasive costs for

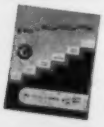
ALL TYPES OF FOUNDRIES

Malleable Foundry Saves $12,000 Annually
Cuts Abrasive Consumption in half

Savings of $1,000.00 a month in abrasive cost are being made at Albion Malleable Iron Co., as a result of switching from a malleable type abrasive to Wheelabrator Steel Shot.

This foundry operates a battery of 8 Wheelabrator Tumblasts, cleaning a variety of regular and pearlitic malleable castings. Consumption of the malleable shot in these machines was at the rate of 20 tons a month. Since changing to Wheelabrator Steel Shot this has been decreased to 10 tons a month, for an annual saving of $12,000.00 on abrasive alone.

More than 1200 firms have standardized on Wheelabrator Steel Shot and are recording inpressive savings. Consistently harder, with greater resistance to breakdown, it lasts longer in use, cleans better, and reduces total cleaning costs.



Write today for Bulletin 89-B — free — for detailed information on Wheelabrator Steel Shot

WHEELABRATOR
CORPORATION

630 South Byrkit Street **Mishawaka, Indiana**

Canadian Offices: Scarborough (Toronto) — Montreal

World's Largest Manufacturer of Airless Blast Cleaning and Steel Abrasives

Circle No. 168, Page 139-140

for the asking

Continued from page 120

Feature article was published in MODERN CASTINGS. *American Foundrymen's Society.*
For Your Copy, Circle No. 70, Page 139-140

Use of oxygen . . . and other gases in metallurgical processes such as flushing molten metals and use in malleable air furnaces included in series of six reports available. *National Cylinder Gas Div., Chemetron Corp.*
For Your Copy, Circle No. 71, Page 139-140

Stress analysis . . . by new technique is thoroughly detailed in brochure. *Tatnall Measuring Systems Co. and Krouse Testing Machine Co.*
For Your Copy, Circle No. 72, Page 139-140

Ladles and skimmers . . . of stainless steel for use in die-casting industry are made in 23 sizes. Send for literature. *Spincraft, Inc.*
For Your Copy, Circle No. 73, Page 139-140

Investment casting . . . process fully explained in 2-p brochure. *Alloy Steel Casting Co.*
For Your Copy, Circle No. 74, Page 139-140

X-ray film processing . . . in 13 minutes claimed for new system developed by this company. Bulletin No. M3-52. *Eastman Kodak Co.*
For Your Copy, Circle No. 75, Page 139-140

Tape recordings . . . of technical talks on many facets of the metalcastings industry are available from AFS. Circle number below for complete listing. *American Foundrymen's Society.*
For Your Copy, Circle No. 76, Page 139-140

Fan noise . . . calculator designed to speed computation of noise levels when additional fans are added to room. Uses some ratings of fans, room size and construction, and amount of insulation. *Propellair Div., Robbins & Myers, Inc.*
For Your Copy, Circle No. 77, Page 139-140

Industrial hearing . . . conservation booklet, 36 pp, stresses need for measuring hearing of personnel in industry, and points up techniques and their application. *Employers Mutuals of Wausau.*
For Your Copy, Circle No. 78, Page 139-140

Roller and wheel conveyors . . . described in catalog complete with line drawing specifications and illustrated applications. *Mathews Conveyer Co.*
For Your Copy, Circle No. 79, Page 139-140

Belt conveyors . . . catalog, 88 pp., includes heavy duty and standard roller bearing conveyors, plus precision ball bearing idlers. *Continental Gin Co.*
For Your Copy, Circle No. 80, Page 139-140

Carbide and steel . . . tools are subject of "code listing and equivalent" sheets available upon request. *Ford Mfg. Co.*
For Your Copy, Circle No. 81, Page 139-140

Titanium . . . booklet, 36 pp, is designed as reference for engineers, metal-

Continued on page 132

New SPECIALIZED

Harbison-Walker Refractories meet the intensified conditions of today's aluminum industry

Within the last couple decades the production of aluminum metal in the United States has trebled and the number of its alloys has increased manyfold. Rapid evolutionary developments created the need for refractories to meet new conditions. The severity of corrosion, more destructive impact accompanying furnace charging and the necessity of avoiding contaminants for meeting rigid alloy specifications—these among other factors have become increasingly important.

Since the first commercial production of aluminum and its alloys, Harbison-Walker brands, primarily of alumina-silica and high-alumina compositions, have continued to fulfill the ever-growing demands. Through unceasing research several refractories, recently developed specifically for aluminum melting furnaces, possess definitely superior properties for maximum durability and best quality of metal. Harbison-Walker's CORALITE XX (85% alumina brick) has established excellent service records in aluminum furnace bottoms and side walls. Several modifications with enhanced properties now are in commercial production.

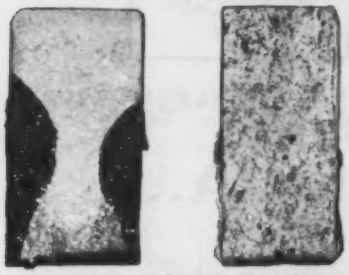
These unique refractories expecially suited for aluminum melting furnaces are here briefly described.

CORALITE 22-58 is a stabilized aluminum phosphate bonded brick containing approximately 85% alumina. It has exceedingly high strength and withstands greater impact and abrasion. Its resistance to wetting and penetration by the molten metal are properties of paramount importance. CORALITE 24-59 is the hard-fired variation, having still higher mechanical strength.

CORALITE 3-59 is a very hard-burned brick containing approximately 85% alumina. It is made with a special bond (patent pending) which contributes to its remarkable strength. As illustrated by the photograph showing results of the laboratory tests, it is exceedingly resistant to penetration and reaction with molten aluminum.

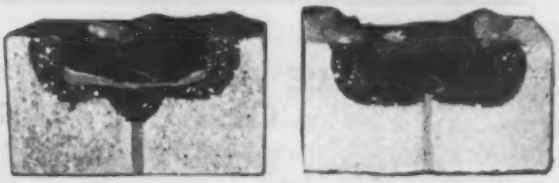
CORALBOND is a phosphate bonded high alumina mortar developed specifically for use in aluminum melting furnaces. Among numerous mortars of many compositions, CORALBOND is very outstanding in its resistance to penetration and corrosion by aluminum alloys at the furnace operating temperatures.

ALUMINUM IMMERSION TEST



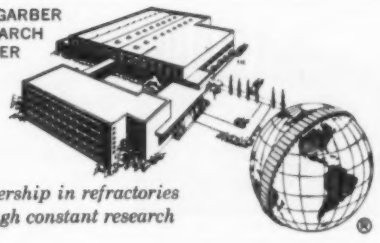
These brick, which were immersed in aluminum alloy at 1400°F. for nine days, show contrast in degree of penetration or wetting between a normal high alumina brick, left, and CORALITE 3-59, right.

MORTAR JOINT TEST



Photograph of Laboratory "Cup Tests" with molten aluminum alloy, shows striking difference in resistance to penetration and corrosion between a widely-used air-setting bonding mortar at the left and the CORALBOND joint at the right. Among many mortars of widely different compositions, CORALBOND—as illustrated in this test—is unmatched.

THE GARBER RESEARCH CENTER



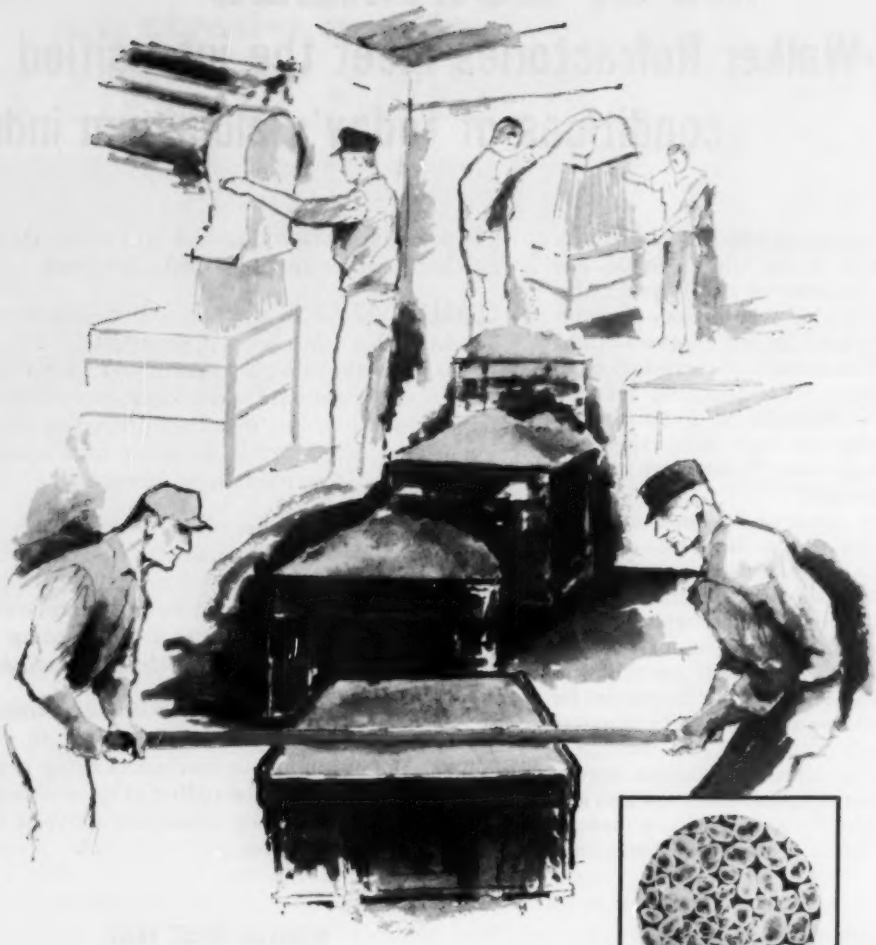
Leadership in refractories through constant research

HARBISON-WALKER REFRACTORIES COMPANY

AND SUBSIDIARIES — GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

World's Most Complete Refractories Service

Circle No. 169, Page 139-140



ALL THE MERITS OF ROUNDED-GRAIN QUALITY ARE YOURS WITH WEDRON SILICA...

New casting techniques produce more accurate castings that require less machining. This is the new money-saving dimension in industry that demands finer foundry sands. Wedron's pure rounded-grain is the answer, in case after case where other sands fail. Where accuracy is demanded, Wedron Silica can meet all specifications and give outstanding results. Make your next order pure, uniform rounded-grain sand from Wedron.

WEDRON SILICA COMPANY

135 South LaSalle Street • Chicago 3, Illinois

Send for illustrated brochure on Wedron sands.

Circle No. 170, Page 139-140

MINES AND MILLS IN THE WEDRON-OTTAWA DISTRICT

dependable Molybdenum in the foundry

Primary justification for increased success in foundry applications of molybdenum is found in the dependability of results. Day after day the foundryman gets the results he needs by adding molybdenum to his melt. Molybdenum may be added to improve tensile and transverse strength, increase impact and fatigue strength, improve wear resistance, increase toughness and strength at higher temperatures, intensify effects of other alloying elements.

The consistency of results in production justifies confidence in MCA molybdenum.

MCA closely controls all of its manufacturing steps and the chemistry of its molybdenum products, hence the uniformity of results.

Complete stocks of molybdenum in all of its metallurgical forms are available through MCA. Technical assistance in meeting tough specifications or solving specialized problems is yours upon request. No obligation, of course.

MOLYBDENUM CORPORATION OF AMERICA

2 Gateway Center Pittsburgh 22, Pa.

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

MCA

Circle No. 171, Page 139-140

foundry trade news

FOUNDRY EQUIPMENT MANUFACTURERS ASSOCIATION . . . will hold its 40th annual meeting Oct. 16-18 at the Greenbrier, White Sulphur Springs, W. Va. Thursday, Oct. 16, will be devoted to morning and afternoon product group meetings consisting of blast cleaning and tumbling, dust and fume control, flask manufacturers, furnaces and accessories, material handling and processing, molding machines. The annual business meeting will be held the morning of Oct. 17. In addition to the election of officers and reports to the membership, a four-man panel will discuss *Marketing of Foundry Equipment*. Participating members and their subjects are: Gordon Seavoy, *Marketing Costs;* Philip Bauer, *Effects of Foreign Competition;* George Pope, *Analysis of the Foundry Industry;* David Davidson, *Technique of Forecasting*. A golf tournament will be held in the afternoon and the annual banquet in the evening. Saturday, Oct. 18, will consist of general sessions. Speakers and their subjects are: E. A. Borch, *Rate of Activity in the Foundry Equipment Industry;* W. B. Wallis, *Glimpses of the New Japan;* Ross L. Gilmore, *Meeting Today's Requirements for Quality Foundry Products*. The general sessions will be followed by an open question period with adjournment scheduled for 1:00 pm. A ladies program will be conducted on Thursday and Friday.

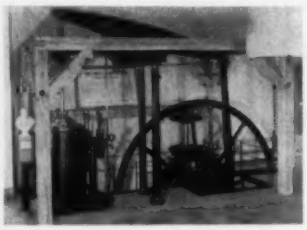
Norton Die Casting Co. . . has been purchased by Skil Corp., Chicago. The Maywood, Ill., die caster will be operated as a subsidiary of Skil with Casmir Delnick continuing as president.

Gra-Iron Foundry Corp. . . is building a 30,000 sq ft addition to its plant at Marshalltown, Iowa. The addition will include office, storage and coremaking facilities.

Schmidt Aluminum Castings Corp. . . has moved to a new plant at St. Petersburg, Florida. Formerly known as Florida Aluminum Castings, the Schmidt Corp. has facilities for producing nonferrous castings from one ounce to 500 lb. The firm is owned by H. W. Schmidt Sr. and Jr. The senior Schmidt operated Arrow Aluminum Castings Co., Cleveland, until his retirement in 1953.

DoALL Company . . . has opened a permanent museum display showing the development of machine tools. The museum is at the DoAll plant near the headquarters of the American Foundrymen's Society, Des Plaines, Ill. The display includes a full scale reproduction of man's first

machine tool, a boring mill invented in 1775 by an English foundryman, John Wilkinson. Development of this machine permitted Wilkinson to produce for James Watt a cylinder bored accurately enough to hold steam pressure. Also included in the DoALL



museum is an actual Watt steam engine built in 1799 which was in regular use until 1945.

Electric Steel Foundry Co. . . . Portland, Ore., has purchased Pacific Alloy Engineering Corp., El Cajon, Calif., from Pelton Steel Casting Co., Milwaukee. The company will operate as a subsidiary of ESCO, and its name has been changed to Pacific Alloy Corp. ESCO districts will act as sales outlets for Pacific Alloy products. Joseph A. Blake, manager of ESCO's southwestern sales district, has been named as president of the subsidiary and Walter H. Dunn who has guided Pacific Alloy since its inception in 1944, will serve as vice-president and general manager. Pacific Alloy is exclusively devoted to the production of aircraft and missile quality castings. Vice-President Oscar Eggen remains in the same capacity. The board of directors is composed of Blake, R. W. deWeese, Charles E. Haney and Henry T. Swigert of ESCO, Dunn of Pacific Alloy Corp., and John P. Apicella, attorney.

Pabcast Corp. . . . has added a 10,000 sq ft building to their plant at Gardena, California. Pabcast operates a fully mechanized brass foundry and a production shop producing aluminum die castings.

Foundry Services, Inc. . . . has opened a plant at Berea, Ohio, replacing its former facilities at Columbus, Ohio. The new operation, placed on a 25 acre site, will include offices, experimental foundry laboratory, plant and shipping facilities.

North American Refractories Co. . . . has expanded its Cleveland warehousing facilities 80 per cent.

Reynolds Metals Co. . . . has added approximately 33,000 tons to its annual primary production capacity with the starting of the first of three potlines at its new St. Lawrence reduction plant at Massena, N.Y. Indications are that about one-third of the St. Lawrence plant's annual production will be delivered as molten metal to a Chevrolet foundry nearing completion close to the Reynolds plant. The remainder of the metal will go through additional production steps for sale in pig or ingot form. Trucks will pick up the molten metal in crucibles. Entering the crucibles at about 1780F, the aluminum can be retained in its molten form for several hours.

Paxton Mitchell Co. . . has completed a new 30,000 sq ft gray iron foundry as an addition to its existing facilities at Omaha, Neb. The new facility will double the company's production.

Nelson Metal Products Co., Inc. . . has been sold to Midland-Ross Corp. The Grand Rapids, Mich. firm produces zinc and aluminum die castings.

New Iron Foundry Co. . . will construct an addition that will double production at its Romulus, Mich. plant.

Speed production of grey iron castings

EXCELLENT FLOWABILITY of Dexocor binder sand mix gives uniform structure throughout cores—and draws are made easily without sticking.

A large midwestern grey iron foundry finds that:

*"Cores made with Dexocor baked through in 40 to 50 per cent less time—saving fuel dollars and permitting more flexible production scheduling. In addition, green cores, even with high stands or overhang, held perfect shape. Cracking of cores, gas defects and metal penetration were virtually eliminated."

—Dexocor offers other advantages: Better moisture control, excellent flowability, quick, easy mixing, blowing, ramming, easy shake-out—especially when used with Mogul or Kordek binder.

Ask for detailed information and technical help in utilizing this new miracle binder. Contact our nearest sales office.

*Source on request.

DEXOCOR® Binder

Other fine products for the Foundry Industry: MOGUL® and KORDEK® Binders • GLOBE® Dextrines

CORN PRODUCTS SALES COMPANY 17 BATTERY PLACE, NEW YORK 4, N.Y.

Circle No. 172, Page 139-140

Buehler

HAND GRINDERS

for fine grinding of metallurgical specimens

The Buehler Hand Grinder No. 1410 is a most convenient piece of equipment to facilitate the hand grinding of metallurgical specimens. Two grinding surfaces are available for two grades of abrasive paper. When four stages of grinding are desired two No. 1410 grinder units are employed. A drum (7½" diameter) at the head of each grinding surface holds up to 150 feet of abrasive paper that can be quickly drawn into position and clamped firmly for use.

Either wet or dry grinding can be conveniently performed on this grinder. The surface beneath the paper is highly polished heavy black plate glass. Overall dimensions are 15" x 26" x 8"; shipping weight 70 lbs. Polishing surfaces 4" x 12".

No. 1415 grinder accommodates standard size abrasive paper sheets. It serves in a like manner as No. 1410 for the convenient hand grinding of specimens. Overall size 17"x 11"x3". Shipping weight 30 lbs.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES—CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Buehler Ltd.

METALLURGICAL APPARATUS

2120 Greenwood Avenue, Evanston, Illinois

Circle No. 173, Page 139-140

"OLIVER" No. 88

TILTING ARBOR

MITER SAW

FINEST ACCURACY • MAXIMUM SAFETY

Fine engineering combines accuracy, convenience and safety. Base and baffle plates encase lower part of saw, assure safety . . . adjustable splitter prevents pinching of work after cut . . . overhead cage guards top of saw in tilted positions. Up to 18" diameter saw size . . . miters and dadoes at square or any angle to 45 degrees. Send for folder giving technical details.

OLIVER MACHINERY COMPANY

GRAND RAPIDS 2, MICHIGAN

Circle No. 174, Page 139-140

Save Money *with* RUDOW STRAINER CORES

Custom Made • Will Duplicate Your Sample or Drawing • Unlimited Design Range • High Heat Resistance • Extra Hard • Saves Time—Trouble

RUDOW quality Strainer Cores cut rejects, cut costs, keep castings free of oxides, slag and impurities—simplify gating control and metal flow, for greater production. We offer you Free Samples of RUDOW Strainer Cores—made like your sample, or from your drawing. Write today—or phone MAin 6-1163.

SEND FOR FREE BULLETINS, PRICES ETC.

RUDOW MANUFACTURING CO.

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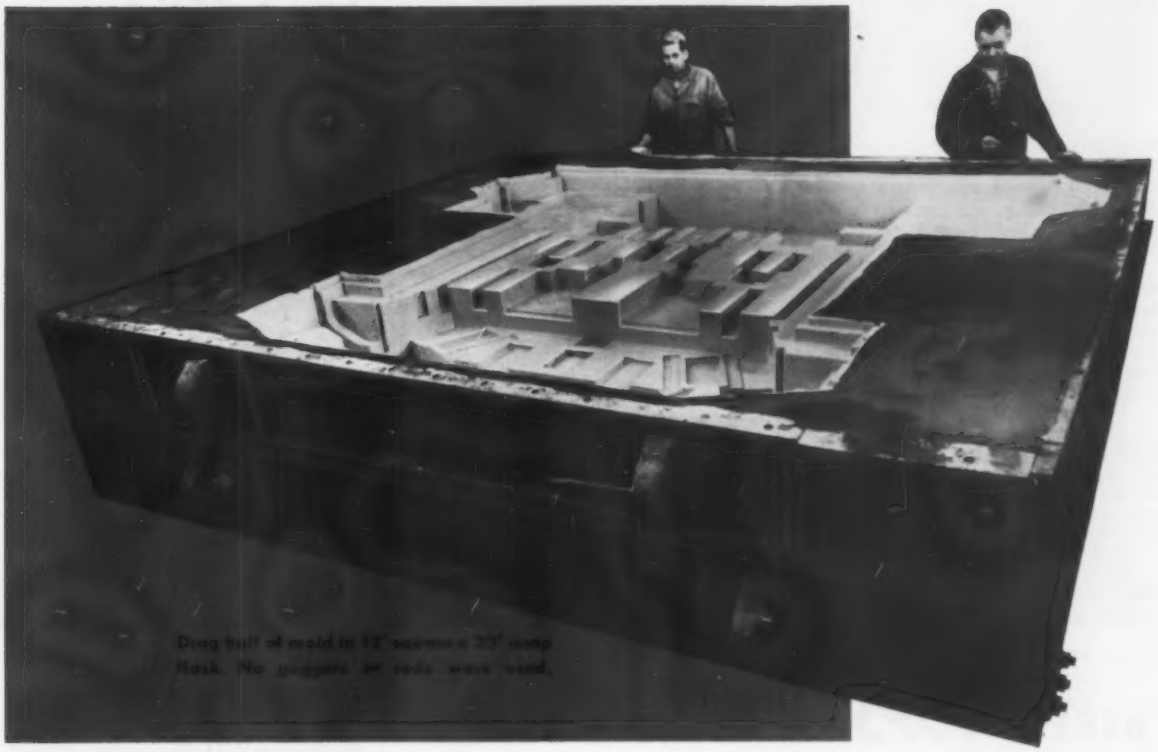
Circle No. 175, Page 139-140

SPECTACULAR RESULTS

in casting automotive dies



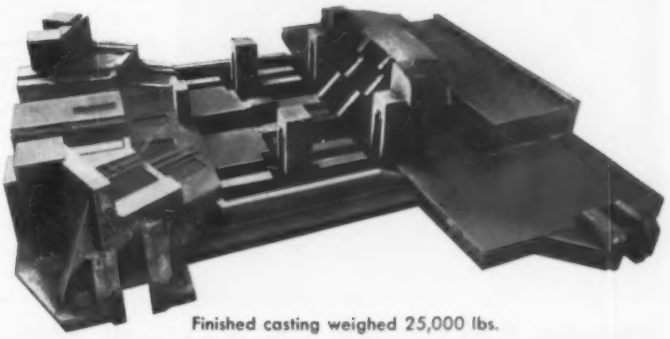
Schneider, Bowman Co., Inc. of Philadelphia is using Kold-Set Binder to achieve significantly improved dimensional accuracy in the production of die castings for the Budd Co.

In the casting shown, considerable machine time was saved due to close tolerances maintained in the making of the casting. The management at Schneider, Bowman Co., Inc. reports a 25% reduction in mold dressing time. Additional savings were realized in mold making in excess of 10%. 2% Kold-Set and 1½% iron oxide were used with 7,000 lbs. of sand. Before drying the mold received two coats of Kold-Set Zircon Wash. No oven baking needed, the mold being dried with a portable heater for eight hours at 450°F.

Let us discuss how the Kold-Setting Binder Process can reduce costs and improve dimensional accuracy of castings for you. *Write or phone!*

Write for Kold-Set Application Studies

Let us send you this new quarterly publication which shows how the Kold-Setting Binder Process is being used by progressive foundries.



Finished casting weighed 25,000 lbs.

KOLD-SET

PRODUCTS FOR FOUNDRY PROGRESS

G. E. SMITH, INC.

246 Washington Road Pittsburgh 16, Pa.

Warehouse Stocks in Chicago, Boston, Detroit, Philadelphia

Kold-Set is Patented in the United States

Circle No. 176, Page 139-140

for the asking

Continued from page 124

lurgists and designers who desire latest technical information. *Harvey Aluminum.*
For Your Copy, Circle No. 82, Page 139-140

Chemical analysis . . . continuous, automatic system said to analyze trace materials down to parts per billion with accuracy of one per cent. Eight-page bulletin. *Technicon Controls, Inc.*
For Your Copy, Circle No. 83, Page 139-140

Gray iron castings . . . and their custom fabrication featured in brochure illustrating 47 types of equipment fabricated by company. *Berlin Chapman Co., Div. Consolidated Foundries & Mfg. Corp.*
For Your Copy, Circle No. 84, Page 139-140

Office automation . . . which reportedly improves your company's competitive position discussed in brochure covering automatic electronic typewriters. Send for booklet. *Remington Rand Div., Sperry Rand Corp.*
For Your Copy, Circle No. 85, Page 139-140

Compressed air dryers . . . with capacities to 3000 cfm to handle compressor output to 600 hp now added to brochure featuring complete line of dryers. *Van Products Co.*
For Your Copy, Circle No. 86, Page 139-140

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Wage picture . . . highlights during 1958 pointed out in government press release available when you use the Reader Service card, last page. *Bureau of National Affairs, Inc.*
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Hoists . . . motor and hand-operated covered in bulletin detailing features, construction, specifications, accessibility, etc. *Wright Hoist Div., American Chain and Cable Co.*
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Better morale . . . can be achieved through better management. Learn how by requesting government leaflet. *Small Business Administration.*
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For Your Copy, Circle No. 91, Page 139-140

Pyrometer supplies . . . thermocouples and components fully discussed in catalog. *Arklay S. Richards Co.*
For Your Copy, Circle No. 92, Page 139-140

Equipment leasing . . . analyzed in booklet. *United States Leasing Corp.*
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For Your Copy, Circle No. 94, Page 139-140

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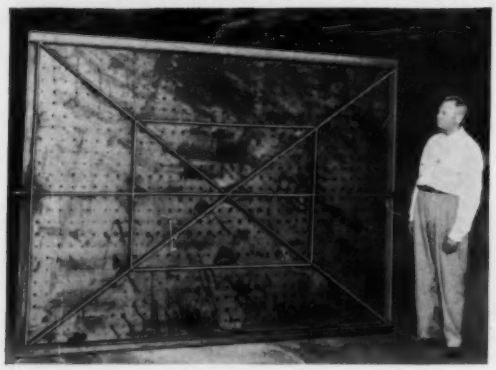

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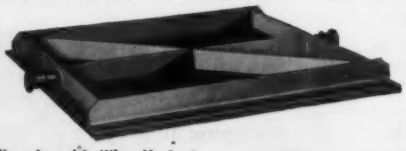

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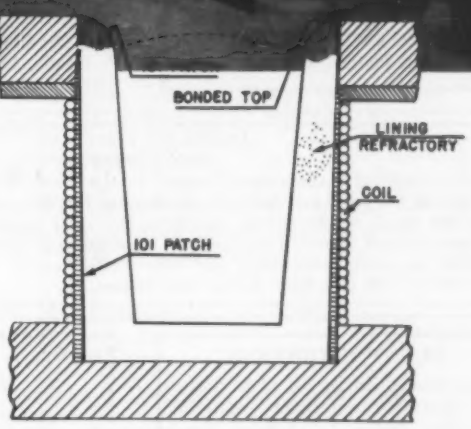

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five advantages

Continued from page 33

the grain fineness of the sand; and green strengths may be varied by changing the sand to oil-binder ratio.

Some special considerations are necessary when pouring magnesium and its alloys. Certain inhibitors used with magnesium are harmful to the commercial oil binders. Such a problem has been overcome by use of an unmodified bentone material.

Re-Use

This oil-bonded system may be re-used, often with only aerating, for several pourings. The sand after shakeout retains heat much longer than a water-green sand. Elevated temperature reduces the sand strength somewhat. Therefore, before re-use the sand must be cooled either by aerating or standing. Once the heap has cooled, the strength will return to a level near that found prior to pouring. In production shops where frequent re-use of a sand is necessary, the need to cool the sand should be carefully analyzed. The solution can usually be found in extra aerating or provision for a larger heap.

During each pouring a small amount of oil and binder is destroyed. With high heat capacity iron and brass, this loss is considerably higher than with magnesium and aluminum.

The general method of re-bonding is to add and mull one per cent bond and one per cent oil with the weak sand. The ratio of oil to binder is higher than that suggested for a new sand mix because the re-used sand acquires fines which tend to adsorb a portion of the oil added. Addition of a catalyst at this point is optional. Mulling time required to re-establish an optimum green strength is similar to or less than that required to bond a new mix.

High mold surface to sand ratios may vaporize more oil than binder and give the sand a dry "feel." In such cases only oil need be added to the mix.

Rebonding and re-use of oil-wet sands is a major factor in their economical application. The materials used with oil-wet sands are more expensive than the ingredients of a simple water-clay green sand. This increased cost of raw materials is offset by the oil sand advantages which have been mentioned throughout this article. Foundries have reported the production of a superior casting for less cost when judged by a complete economic survey.(4)

*At room temperature the heat conductivity of oil is approximately 0.08 to 0.10 Btu/hr-ft °F – water is 0.35 Btu/hr-ft °F.

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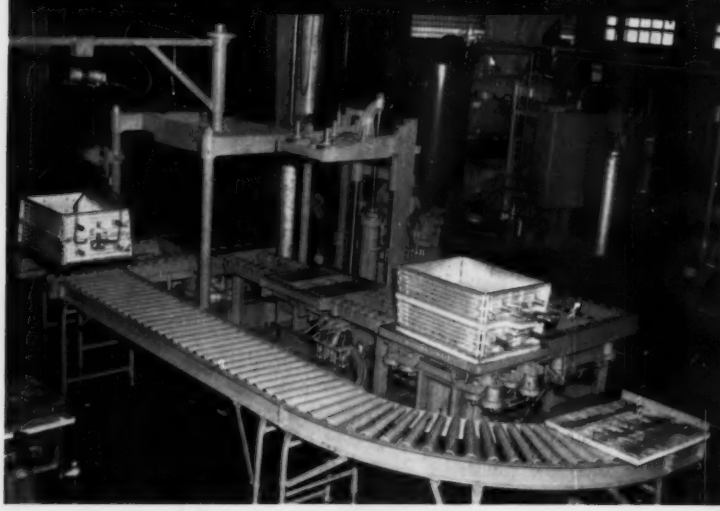

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PROVEN PRODUCTS FOR THE FOUNDRY INDUSTRY

RCI

Creative Chemistry ...Your Partner in Progress

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When close tolerances are vital

RCI FOUNDREZ INSURES ACCURACY IN HICA SHELL MOLDING PROCESS

Shreveport, La. —HICA, INC., reports that shell molds made with Reichhold's FOUNDREZ 7504 powdered phenolic resin produce "High Integrity CAstings" for manufacturers of chemical and milk processing equipment, aircraft, missile, pump, valve and burner parts. HICA pours stainless and other alloys on intricate jobs requiring extremely close tolerances.

HIGHEST DEPENDABILITY

In a recent interview Phillip R. Johnson, HICA shell molding foreman, said "The dependability of RCI's FOUNDREZ recently helped us supply a large order of complicated castings without a single reject by our customer. With FOUNDREZ, we are able to avoid the warpage and cracking frequently encountered with other resins. Nor have we experienced any problem that could be attributed to our use of FOUNDREZ."

HICA *team ready to close cope and drag halves of plug valve handle adapter mold after cores have been set in place.*

HICA'S *shell molding department. Up-to-date methods and machines help produce accurate, economical castings.*

ECONOMY IMPORTANT

Besides dependability and quality, economy played a significant part in HICA'S choice of FOUNDREZ. "The superior bonding qualities of RCI's FOUNDREZ 7504," said Mr. Johnson, "allow us to use less resin per pound of sand, affording us substantial savings in our production run. It's easy to see why we use FOUNDREZ exclusively in all our shell molding techniques."

VARIETY OF RESINS

Reichhold's FOUNDREZ 7500 series of powdered phenol-formaldehyde resins, designed especially for shell molding, includes:

FOUNDREZ 7500 — a general purpose phenol-formaldehyde resin. Features long flow and cure. This product is especially applicable to intricate-pattern work.

FOUNDREZ 7504— formulated for intermediate flow and long cure properties. Ideal for the jobbing shop where many different types of castings are made. May be employed on a variety of pattern contours.

FOUNDREZ 7506— has the shortest flow and fastest cure of the series. Compounded for high speed production of shells. Most suitable where foundry production involves long runs of a few types of castings.

If you would like further information on the FOUNDREZ 7500 series, write for Technical Bulletin F-3-R. Reichhold Chemicals, Inc., RCI Building, White Plains, New York.